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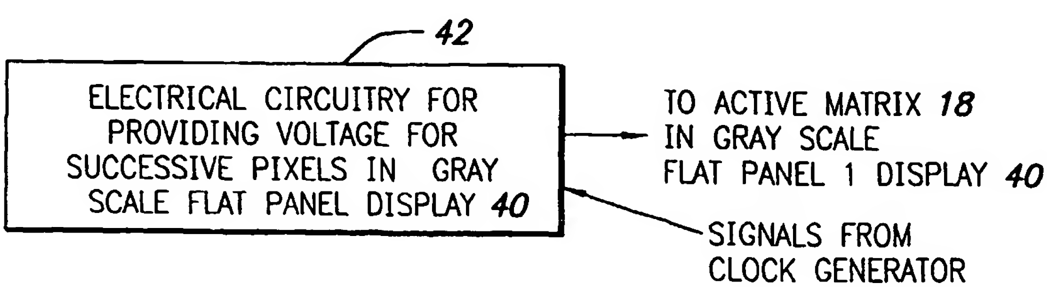
(54) Title: SYSTEM FOR, AND METHOD OF, FORMING GRAY SCALE IMAGES IN A FLAT PANEL DISPLAY



(57) Abstract: A flat panel display (40) constructed to provide a color image represented by a particular number of color pixels is modified to present a gray scale image (image displayed on 40) represented by a number of pixels greater than the particular number. In the modification, color filters are removed from the flat panel display to provide, for each color pixel, three gray scale pixels (34a, 34b, 34c) corresponding to the three positions receiving in the color pixel the red, green, and blue components from the color filters. Electrical circuitry (42) connected with the flat panel (40) introduces a gray-scale voltage (the output voltage from 42 to active matrix 18), preferably represented by a plurality of binary bits, for each gray scale pixel (34a, 34b, 34c) to provide for a display of the gray scale image in the display monitor. (40).

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SYSTEM FOR, AND METHOD OF, FORMING GRAY SCALE IMAGES IN A FLAT PANEL DISPLAY

This invention relates to a system for, and method of, providing a flat panel display constructed to provide color images and modifying the flat panel display to provide gray scale images. The system and method of this invention provide for the production of gray scale images with a greater resolution than that provided by wide panel displays such as those provided by cathode ray tubes.

BACKGROUND OF THE INVENTION:

X-ray images are generally provided on a gray scale basis. For example, a chest x-ray to determine a cancer or an x-ray to determine a fracture of a bone is generally provided as a black-and-white image. It is desirable to enhance the resolution of the image by providing sharpened contrasts between black and white and different shades of gray. An enhanced resolution of an image may allow a physician studying the image to see problems (e.g., cancers and bone fractures) that the physician would not see if the image did not have the enhanced resolution.

X-ray images are generally examined by a system including a cathode ray tube. This system has a limited number of advantages and several significant disadvantages. An advantage is that the system provides a sharpened contrast between black and white when the image is viewed in a dark environment. A corollary disadvantage is that the system provides a weakened contrast between black and white and various shades of gray when the image is viewed in a light environment. Most viewers would prefer to study an x-ray image in a light environment because such an environment involves a decreased strain on the viewers' eyes, particularly when the viewers have to perform other functions such

as reading books and documents between the times that the viewers study the x-ray images.

There are other disadvantages to the use of a system including a cathode ray tube to view an x-ray image. For example, the cathode ray tube in the system generates a considerable amount of heat, even when images are not generated in the cathode ray tube, when the system is activated. Another disadvantage is that the cathode ray tube occupies a considerable amount of space, particularly in the direction of the depth of the cathode ray tube. A further disadvantage is that the distinction between black and white and various shades of gray in the cathode ray tube becomes weakened when the system is disposed in a normally light environment.

There are still other disadvantages with the systems which are now in use and which employ cathode ray tubes. It is sometimes desired to emphasize a particular portion of a gray scale image in relation to other portions of the gray scale image. For example, it may be desired to emphasize a portion of a chest x-ray where there appears to be a cancer. It is difficult to do this with systems which employ a cathode ray tube to provide the gray scale image.

BRIEF DESCRIPTION OF THE PREFERRED EMBODIMENTS OF THE INVENTION

In a preferred embodiment of the invention, a flat panel display may provide a gray scale image. This minimizes the depth of the display, at least in comparison to the depth of the cathode ray tubes (CRT) now in use. Heat dissipation is also minimized in comparison to the heat generated in the CRT tube. The flat panel display provides an additional advantage in that it provides an enhanced contrast

between black and white and gray scale pixels, particularly when the image is viewed in a light environment. A light environment is what most viewers prefer in contrast to a dark environment.

In a preferred embodiment of the invention, a flat panel display constructed to provide a color image represented by a particular number of color pixels (generally in a row-column matrix) is modified to present a gray scale image represented by a number of pixels greater than the particular number. In the modification, color filters are removed from the flat panel display to provide, for each color pixel, three (3) gray scale pixels corresponding to the three (3) portions receiving in the color pixel the red, green and blue components from the color filters.

Electrical circuitry associated with the flat panel introduces a gray-scale voltage, preferably represented by a plurality of binary bits, for each gray scale pixel to provide for a display of the gray-scale image in the display monitor. Thus, gray scale resolution may be enhanced by providing the flat panel display with three (3) times as many pixels as in the CRT tubes now in use.

Since each color pixel in the flat panel display would normally be square, the height of each gray scale pixel is three (3) times greater than the pixel width. The circuitry may accordingly process three (3) gray scale voltages at different portions of the pixel in the vertical direction by averaging the voltages or choosing the brightest (or the darkest) of the three (3) images represented by the voltages. Alternatively, the nine (9) voltages for the three (3) gray scale pixels in each color pixel may be convoluted.

In another preferred embodiment, the system and method of the preferred embodiment of this invention increase the effective number of binary bits representing the gray scale value in each pixel and accordingly enhance the resolution of the gray scale image provided by each pixel.

Color filters are not included in a flat panel display, thereby providing for each pixel three (3) gray scale portions respectively corresponding to the portions normally receiving in each pixel the red, green and blue components from the color filters. In one embodiment, each of the three portions of each pixel receives a digital representation indicated by a particular number (e.g. 8) of binary bits. The display accordingly provides a gray scale image.

In one preferred embodiment, each of the three portions of each pixel receives a digital representation indicated by a particular number (e.g. 8) of binary bits. The binary bits for each pixel portion are introduced to a look-up table which converts the binary indications to a digital representation different from that provided by the binary indications. These digital representations for each pixel portion are converted to analog voltages which produce in the display screen monitor an image with an enhanced gray scale.

In a preferred embodiment, each of the three (3) portions for each pixel receives a digital representation indicated by a particular number (e.g. 8) of binary bits representing 256 different values. 256 values may be selected from the 766 gray scale values cumulatively provided by the three (3) pixel portions. These 256 digital representations are converted to analog voltages which produce on the display screen monitor an image with an enhanced gray scale resolution. The 256 digital values selected may provide in the display a particular correction curve (e.g. gamma correction) of voltage v. brightness.

In another preferred embodiment, a first one of the portions of each pixel provides a value indicated by the particular number (e.g. 8) of binary bits. The binary bits in each of the other two (2) portions of each pixel may provide interpolations between the particular one of the 256 values represented in the first portion and the next progressive one of the 256 values represented in the first portion. Particular values from the first pixel portion and particular ones of the interpolated values from the other two (2) pixel portions are converted to analog voltages to provide 256 different analog voltages. These 256 analog voltages provide on the display screen monitor an image representing any desired relationship including gamma correction.

In other preferred embodiments, binary indications from different portions in a pixel are combined before being introduced to a look-up table. For example, twelve (12) bits from the 24 binary bits in the three (3) portions of each pixel are introduced to a look-up table to obtain a digital representation from the look-up table. The digital representations for the different pixels produce a gray scale image on a flat panel display. Alternatively, the 24 binary bits cumulatively in the three (3) portions of each pixel may be divided into two (2) binary indications, each of 12 bits. Each of these binary indications is introduced to a separate look-up table. Each of the two (2) look-up tables provides for a gray scale image in an individual one of two (2) flat panel displays.

In a preferred embodiment, the presentation of successive images in one of a landscape mode and a portrait mode is converted instantaneously by hardware to the other one of the landscape and portrait modes. The preferred embodiment includes a microprocessor for providing binary indications for the gray scale of each pixel (or each pixel portion). The binary indications are stored as in a frame buffer. The stored indications are introduced to hardware such as an interface board which

converts the sequence the sequence of the binary indications from the one of the landscape and portrait modes to the other one of the landscape and portrait modes. The binary indications from the interface board are converted to corresponding analog voltages. The analog voltages are introduced to the pads (or pixel portions) in the flat panel display to produce a gray scale image in the flat panel display. The image has an enhanced gray scale.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

Figure 1 is a schematic view, partially in section, of a flat panel display of the prior art, the flat panel display illustratively constituting an active matrix liquid crystal display;

Figure 2 is an exploded perspective view of the prior art flat panel display shown in Figure 1, the display including color filters for providing a color image, and also shows the percentage of the intensity of the light introduced to the flat panel display and passing through each of the successive layers or elements in the flat panel display;

Figure 3 is a schematic perspective view showing how light is passed, or not passed, through the flat panel display of the prior art depending upon the introduction, or lack of introduction, of a control voltage to the active matrix in the display;

Figure 4 is a view schematically showing how the light rays become twisted relative to the polarizers in the flat panel display of the prior art, the twisting of the light for each pixel being dependent upon the introduction of the control voltage to the active matrix in the display for the pixel;

Figure 5 is a curve showing the relationship between the magnitude of the control voltage applied for each pixel to the active matrix in the flat panel display of

the prior art and the intensity of the light passing through the flat panel display for the pixel;

Figure 6 is a schematic view showing the relative sizes of the color pixels produced by the prior art flat panel display shown in Figures 1-4;

Figure 7 is a view, similar to that shown in Figure 1, of a gray scale flat panel display constituting a preferred embodiment of the invention, the flat panel display being formed by removing the color filters from the prior art flat panel display shown in Figures 1-4;

Figure 8 is a simplified circuit diagram of the electrical circuitry for producing a scanning of the successive pixels in the flat panel display of Figure 7 to produce a gray scale image on the face of the monitor in the flat panel display;

Figure 9 is a schematic circuit diagram showing how voltages of different magnitudes may be provided for different portions of each pixel in a vertical direction substantially perpendicular to the horizontal direction in which the successive pixels in each row are scanned and how the voltages for the different vertical portions of each pixel may be processed, as by averaging, to obtain a median gray scale voltage for producing a gray scale image in the complete area of the pixel;

Figure 10 shows electrical circuitry in block form for processing voltages in different portions of each gray scale pixel in the vertical direction to select a single one of the voltages, dependent upon the relative magnitudes of the voltages, for producing a gray scale image for the gray scale pixel in the flat panel display shown in Figure 7;

Figure 11a establishes a program for a group of pixels in the flat panel display for performing a convolution;

Figure 11b provides data for the group of pixels for operating in conjunction with the program established in Figure 11a to provide the convolution;

Figure 12 shows electrical circuitry in block form for producing a convolution of the voltage in different portions of a group of successive gray scale pixels to provide a voltage for producing a gray scale image for the group of pixels in the flat panel display shown in Figure 7;

Figure 13 is a schematic diagram of an electrical system for enhancing the contrast between black images in some pixels and light images in other pixels to sharpen the image on the monitor in the flat panel display;

Figure 14 is a schematic representation of a plurality of response curves each of which shows the relationship between an analog voltage along a horizontal axis and a brightness of pixel response along a vertical axis;

Figure 15 is a schematic circuit diagram in block form of electrical stages which may be used to provide the relationship between the analog voltage and pixel brightness as shown in Figure 14;

Figure 16 is a simplified block diagram of a prior art embodiment which includes a display such as a cathode ray tube;

Figure 17 is a simplified block diagram of another embodiment of the invention, this embodiment preferably incorporating the flat panel display shown in Figure 7 and including a look-up table for introducing voltages to a flat panel display to produce a gray scale image on the flat panel display;

Figure 18 shows a curve providing an interrelationship between digital representations (as indicated by analog voltages) along a horizontal axis and different gray scale (or brightness) levels along a vertical axis;

Figure 19 is a simplified block diagram of another preferred embodiment of the invention, this embodiment including a flat panel display and a look-up table;

Figure 20 is a simplified block diagram of another preferred embodiment of the invention, this embodiment also including a flat panel display and a look-up table;

Figure 21 is a simplified block diagram of another preferred embodiment of the invention, this embodiment including two (2) flat panel displays and two (2) look-up tables each associated with an individual one of the flat panel displays to provide a gray scale image on the individual one of the flat panel displays;

Figure 22 is a simplified block diagram of another preferred embodiment of the invention, this embodiment including a flat panel display and a look-up table for producing a pseudo color image on the monitor of a flat panel display;

Figure 23 is a schematic diagram of successive sweeps of lines of the pixels in a display such as a cathode ray tube when the display is disposed in a landscape mode;

Figure 24 is a schematic diagram of successive sweeps of lines of the pixels in the display such as a cathode ray tube when the display is disposed in a portrait mode;

Figure 25 is a schematic diagram of successive sweeps of lines of the pixels in a display such as a cathode ray tube with the display in the landscape mode and shows the difficulty in converting the pixel sweeps from the landscape mode to the portrait mode;

Figure 26 is a schematic diagram of successive sweeps of lines of the pixels in a display such as a cathode ray tube with the display in the portrait mode and shows additional difficulty in converting the pixel sweeps from the landscape mode to the portrait mode;

Figure 27 is a schematic diagram of the pixel sweeps in the portrait mode in the display when the sweeps have been converted from the landscape mode to the portrait mode;

Figure 28 is a schematic circuit diagram in block form of a prior art system for converting an image on the face of a display from a landscape mode to a portrait mode; and

Figure 29 is a schematic circuit diagram in block form of a system constituting a preferred embodiment of the invention for converting an image on the face of a flat panel display from a landscape mode to a portrait mode.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS OF THE INVENTION

Figures 1-4 show a flat panel display, generally indicated at 10, for providing in the prior art a color image on a face of a polarizer 12 which may be considered to act as a display monitor. The flat panel display 10 shown in Figures 1-4 may constitute an active matrix liquid crystal display but a passive matrix liquid crystal display may also be used without departing from the scope of the invention.

The flat panel display 10 includes a flat layer or element 14 (Figure 2) which passes all of the light from a light source (not shown) in back of the flat layer or element. The intensity of the light passing through the flat layer or element 14 is indicated at "100%" to the right of the flat layer 14 in Figure 2 to indicate that all of the light introduced to the flat layer or element passes through the flat layer or element. A polarizer 16 is disposed adjacent the flat layer 14. The polarizer 16 is constructed to polarize the light in a particular direction. An active matrix 18 is disposed adjacent the polarizer 16. As will be described in detail subsequently, the active matrix 18 comprises an electrode which receives a voltage having a magnitude representing the gray scale image to be provided for each pixel in the monitor in the flat panel display 10 and which provides for the production of a gray scale image at the pixel in accordance with such voltage magnitude. The voltage for each pixel may be provided in a digital form by a particular number of binary bits. The active matrix 18 passes approximately forty percent (40%) of the light introduced to the flat panel or element 14, this percentage being produced when the

active matrix 18 receives a voltage for passing a maximum amount of the light introduced to the active matrix. The indication of 40% for the passage of light through the active matrix 18 is shown to the right of the active matrix in Figure 2.

An electrode 20 is disposed adjacent the active matrix 18. The electrode 20 is provided with a reference voltage relative to a ground potential to provide a voltage reference to turn the flat panel display 10 on or off. An insulating layer 22 (Figure 1) made from a suitable material such as a polyamide is adjacent to the electrode 20. A spacer 24 made from a suitable insulating material is disposed between the insulating layer 22 and an insulating layer 26, also made from a suitable material such as a polyamide, to provide a precise separation between the insulating layers 22 and 26. A suitable liquid crystal material 28 (Figures 1 and 2) is disposed in the space between the insulating layers 22 and 26. The liquid crystal material 28 preferably has anisotropic properties. An electrode 30 (Figure 2) is disposed adjacent to the liquid crystal material 28. The electrode 30 may be made from the same material as the electrode 20 and may be provided with a reference potential such as ground. Approximately twenty percent (20%) of the intensity of the light from the layer 14 passes through the electrode 30.

Color filters 32 may be disposed adjacent the electrode 30. Three (3) filters (red, green and blue) may be provided for each pixel, generally indicated at 34 (Figure 6), displayed on the face of the monitor in the flat panel display 10. The color filters 32 are disposed adjacent individual portions of the pixel 34 such as portions 34a, 34b and 34c in the pixel 34 in Figure 6. The pixel portions 34a, 34b and 34c respectively provide hues of red, green and blue. The relative intensities of the color respectively provided on the pixel portions 34a, 34b and 34c of the pixel 34 determine the color or hue produced in the pixel. The light passing through the color filters 34a, 34b and 34c for each filter are introduced to the polarizer 12.

Because of the operation of the color filters 32, approximately only three percent (3%) of the intensity of the light introduced to the flat panel or element 14 passes through the polarizer 12.

As shown schematically in Figure 3, the polarization of the polarizer 12 may be displaced by substantially 90° from the polarization of the polarizer 16 depending upon the direction in which the liquid crystal material 28 is disposed. The liquid crystal material 28 is twisted in a direction substantially perpendicular to the direction of polarization of the polarizer 12 when a reference voltage is produced between the electrodes 20 and 30 and an activating or voltage control is applied to the active matrix 18. This prevents light passing through the polarizer 16 from the flat layer 14 from passing through the polarizer 12. For any color pixel 34 where light does not pass through the polarizer 12, a black image is accordingly produced. When the reference voltage is applied between the electrodes 20 and 30 and an activating or control voltage is not applied to the active matrix 18, the polarization of the liquid crystal material 28 is not twisted so that light passing through the polarizer 16 from the flat layer or element 14 passes through the polarizer 12.

Figure 5 is a curve illustrating the relationship between the magnitude of the voltage applied to the active matrix 18 for any pixel 34 and the intensity of the transmission of light through the polarizer 12 for that pixel. As will be seen, no light passes through the polarizer 12 when a voltage equal to or greater than approximately three and one-half volts is applied to the active matrix 18. This results from the twisting of the liquid crystal material 28 as a result of the voltage applied to the active matrix 18.

On the other hand, light of a maximum intensity passes through the polarizer 12 when no voltage or a voltage less than approximately one and one-half volts (1.5v) is applied to the active matrix 18. This results from the fact that the liquid crystal material 28 is not twisted. For voltages applied to the active matrix 18 between approximately one and one-half volts (1.5V) and approximately three and one-half volts (3.5V) for any pixel 34, an image of a reduced intensity will be produced. The reduction in the intensity of the image is dependent upon the magnitude of the voltage applied to the active matrix 18 between approximately one and one-half volts (1.5V) and approximately three and one-half volts (3.5V).

Figure 7 illustrates a flat panel display, generally indicated at 40, constituting a preferred embodiment of the invention. The preferred embodiment 40 is constructed to provide a gray scale image on the face of the monitor in the flat panel display. The preferred embodiment 40 is similar to the prior art embodiment 10 shown in Figures 1-4 except that the color filters 32 are removed. By removing the color filters 32, each pixel 34 is separated into three (3) pixels 34a, 34b and 34c. Each of the pixels 34a, 34b and 34c is independent in the gray scale from the other ones of the pixels 34a, 34b and 34c. Each of the pixels 34a, 34b and 34c is accordingly able to receive a voltage independent of the voltages applied to the other ones of the pixels 34a, 34b and 34c and to provide a gray scale indication representative of the applied voltage and independent of the gray scale indications provided by the other ones of the gray scale pixels 34a, 34b and 34c.

As will be seen, the pixels 34a, 34b and 34c are disposed at progressive positions in the horizontal direction. This causes the number of pixels in each row on the face of the monitor in the flat panel display 40 to be tripled relative to the number of pixels in each row in the flat panel display 10 of the prior art and relative to the number of pixels in each row in a cathode ray tube of the prior art. This

enhances the resolution of the gray scale image in the flat panel display 40 comparison to the resolution which can be obtained if the number of pixels in each row in the gray scale image corresponded to the number of pixels in each row in the flat panel display 10 providing a color image in the prior art. It also enhances the resolution of the image relative to the resolution provided by a cathode ray tube in the prior art.

There are other significant advantages to the embodiment shown in Figure 7. This results from the fact that the color filters 32 in the embodiment 10 shown in Figures 1-4 cause approximately seventeen percent (17%) of the light intensity introduced to the flat panel or element 14 to be lost. By removing the color filters 32 in the gray scale embodiment shown in Figure 7, the intensity of the light passing through the polarizer 12 increases from approximately three percent (3%) of the light intensity introduced to the flat panel or element 14 to approximately twenty percent (20%) of the light intensity introduced to the flat panel or element 14. This is almost a six (6)-fold increase in the intensity of the light passing through the polarizer 12 for the gray scale embodiment shown in Figure 7 in comparison to the intensity of the light passing through the polarizer 12 in the color embodiment shown in Figures 1-4.

The enhancement in the intensity of the light passing through the polarizer 12 in the gray scale embodiment 40 shown in Figure 7 provides other advantages in addition to those described above. For example, the enhancement in the intensity of the light passing through the polarizer 12 in the gray scale embodiment 40 causes an enhanced contrast to be produced between a black image in one of the pixels 34a, 34b and 34c and a light image in another one of the pixels 34a, 34b and 34c. Furthermore, it provides for a disposition of the flat panel display 40 in a light environment such as a brightly lit room. The disposition of the gray scale flat panel

display 40 in a brightly lit environment provides for the operability of the display in a broadened range of applications in a hospital. For example, the preferred embodiment 40 can be operated in a central area in a ward in a hospital where all of the nurses in the ward are located and where the central area has to be well lit so that the nurses can maintain, update and read records relating to the patients in the ward.

The operability of the preferred embodiment 40 in a brightly lit environment is in contrast to an optimal operation of a cathode ray tube system of the prior art in a dimly lit environment. An operation of the prior art cathode ray tube embodiment in a dimly lit environment is disadvantageous, particularly when the viewer has to read documents between the times that the viewer looks at the image on the face of the cathode ray tube.

Electrical circuitry 42 is schematically shown in Figure 8 for introducing voltages representing gray scale images to the successive pixels 34a, 34b and 34c in each horizontal line in the monitor in the flat panel display 40 shown in Figure 7. The electrical circuitry 42 may be similar to that provided for the color image on the face of the monitor in the flat panel display 10 in Figures 1-4 except that it occurs at a frequency three (3) times as great as the frequency of the voltages introduced to the flat panel display 10. This results from the fact that each pixel 34 in the flat panel display 10 in Figures 1-4 is now divided into the individual pixels 34a, 34b and 34c in the flat panel display 40 in Figure 7. The voltages from the electrical circuitry 42 may be introduced to a line 44 which is connected to the active matrix 18 in the flat panel display 40. The introduction of the voltages to the active matrix 18 in the flat panel display 40 may be synchronized with the production on the line 44 of clock signals from a clock generator.

As will be appreciated, since the pixel 34 is substantially square, the height of each of the pixels 34a, 34b and 34c is now three (3) times greater than the width of each of the pixels. Separate voltages may be provided for each progressive one-third (1/3) of the vertical distance of each of the pixels 34a, 34b and 34c. These voltages may be processed in different ways to provide a single individual voltage for each of the pixels 34a, 34b and 34c or a single individual voltage for a group constituting the pixels 34a, 34b and 34c. Processing the different voltages in the vertical direction for each of the pixels 34a, 34b and 34c offers certain advantages which will be described subsequently for each of a plurality of the different processing techniques.

One way of processing the plurality of voltages for the different portions of each of the pixels 34a, 34b and 34c in the vertical direction is to average each of the plurality of voltages produced in the vertical direction for the pixel. For example, the three (3) voltages in the vertical direction for the pixel 34a may be averaged. This averaging provides for the production of a single voltage for the pixel 34a. The averaging may be processed by averaging circuitry 50 in Figure 9. The averaging circuitry 50 receives voltages on three (3) input lines 52a, 52b and 52c for each gray scale pixel such as the pixel 34a. The voltages on the lines 52a, 52b and 52c represent gray scale images at different portions of each pixel, such as the pixel 34a, in the vertical direction. The averaged voltage produced by the circuitry 50 is provided on a line 54 at the output of the circuitry.

The production of a single averaged voltage for each pixel is advantageous because it provides a median gray scale value for the different portions of the pixel 34a in the vertical direction. Such averaging circuitry is known in the prior art for different applications than gray scale representations for the different pixels in a gray scale flat panel display. It is believed that a person of ordinary skill in the art

will be able to apply such averaging circuits to average the pixel values in a gray scale flat panel display.

Another way of processing the plurality of voltages for the different portions of each of the pixels 34a, 34b and 34c in the vertical direction is to select the voltage with an extreme magnitude in the plurality of voltages in the vertical direction for each of the pixels. For example, the voltage with the lowest value may be selected from the plurality of voltages for the different portions of the pixel 34a in the vertical direction. This voltage is then applied to the complete area of the pixel 34a. This provides for a brightening of the image produced on the face of the monitor in the flat panel display 40 while still providing a contrast between successive pixels. Alternatively, the voltage with the highest magnitude may be selected from the plurality of voltages for the different positions of the pixel 34a in the vertical direction. This voltage is then applied to the complete area of the pixel 34a. This will tend to darken the gray scale image displayed on the face of the monitor in the flat panel display 40 while still providing a contrast between successive pixels.

The selection of the voltage with the extreme magnitude from the plurality of the voltages for the different portions of each pixel in the vertical direction may be provided by a voltage comparator 60 in Figure 10. Such a comparator is known to persons of ordinary skill in the art for applications. It is believed that a person of ordinary skill in the art will be able to apply such a comparator to determine the extreme voltage among the voltages applied to the different vertical portions of the pixel. The comparator 60 receives voltages on input lines 62a, 62b and 62c for the different portions in the vertical direction of each pixel such as the pixel 34a. The comparator 60 compares the magnitudes of the different voltages for each pixel and selects one of the voltages depending upon its magnitude relative to the magnitudes

of the other voltages for the pixel. The selected voltage is provided on an output line 64 from the comparator 60.

A third way of processing the voltages for the different portions of each of the pixels 34a, 34b and 34c in the vertical direction is to process the voltages in a form of a convolution. It will be appreciated that many forms of convolutions may be known to a person of ordinary skill in the art. Because of this, it is believed that one example of a convolution should be sufficient to establish the concept and practice of performing a convolution in selecting values for each of the pixels 34a, 34b and 34c. This example is shown in Figures 11a and 11b. Figure 11a establishes a program for providing a convolution. Figure 11b provides data for the different portions of each of the pixels 34a, 34b and 34c in the vertical direction. The central value "6" in Figure 11b is multiplied by the central value "9" in Figure 11a to give an intermediate value of 54. The values in Figure 11b (except for the central value "6") are summed to give a value of 40. The value of 40 is then subtracted from the value of 54 to provide a value of 14. The value of 14 indicates the gray scale to be provided for the area defined by the pixels 34a, 34b and 34c on the face of the monitor in the flat panel display 40. The convolution is provided by convoluting circuitry and software generally indicated at 70 in Figure 12.

As previously indicated, each pixel has three (3) portions 34a, 34b and 34c (Figure 6) each of which would provide one of the red, green and blue hues if the pixel were providing color. Each portion is defined by a digital representation having a particular number of binary bits. This particular number may illustratively be eight (8). When eight (8) binary bits are provided in each of the pixel portions 34a, 34b and 34c, the binary bits in each portion can represent values between "1" and "256".

A microprocessor 80 (Figure 15) can be associated with the portions 34a, 34b and 34c for each of the pixels 34. The microprocessor 80 processes the binary bits from the portions 34a, 34b and 34c for each pixel 34 so that the number of available values is increased from (256) to 766. The number of available values is (3)256-2=766 because each of the portion 34b and the 34c does not provide a value for the last digital position. From the standpoint of a $\log_2$ analysis to determine the equivalent number of binary bits this provides an increase in the effective number of binary bits for each pixel 34 from 2^8 to approximately $2^{9.58}$ binary bits.

The increase from 2^8 to approximately $2^{9.58}$ bits by cumulatively providing the pixel portions 34a, 34b and 34c for each pixel position may be seen from the following. The pixel portion 34a provides 256 binary positions, each representing 2^8 binary bits. Since $2^8 = 256$, the pixel portion 34a indicates 2^8 binary bits. The pixel portion 34b provides 256 additional positions, each indicating an individual value of the 9th binary bit. As will be appreciated, the 9th binary bit is represented by 256 binary values. Thus, the pixel portions 34a and 34b cumulatively indicate nine (9) binary bits. The 10th binary bit is indicated by an additional 512 binary positions. However, the pixel portion 34c can provide only 254 positions. This is equivalent to approximately 0.58 of the 10th binary bit. Thus, the pixel portions 34a, 34b and 34c cumulatively indicate $2^{9.58}$ binary bits.

A gray scale image with a digital representation of $2^{9.58}$ binary bits provides a significantly enhanced contrast between different shades of gray than a gray scale image with a digital representation of only 2^8 bits. Furthermore, this enhanced contrast between light pixels and dark pixels is provided in the preferred embodiment of this invention without changing the number of pixels in the display monitor.

A curve 82 in Figure 14 provides an indication of the brightness response of the monitor in the flat panel display 40 for different digital driving levels. In the curve 82 in Figure 14, analog voltages corresponding to the different digital driving levels are shown along the horizontal axis and different brightnesses are shown along the vertical axis. As will be seen, the response of the monitor in the flat panel display is not linear in the curve 82 for progressive values of the analog voltage. A curve 84 is also shown in Figure 14. The curve 84 constitutes a gamma correction curve. It shows the resolution of the human eye to brightness at different analog voltage levels corresponding to different digital driving levels. The curve 84 provides a different response of voltage vs brightness than the curve 82.

Two hundred and fifty six (256) values may be selected from the 766 values provided by the three (3) portions 34a, 34b and 34c of each pixel. This corresponds to a binary value of 2^8 when each of the pixel portions 34a, 34b and 34 c is represented by eight (8) binary bits. The 256 values are selected by the programming of the microprocessor 80. This is shown in Figure 15 which indicates the microprocessor 80 and also indicates the programming of the microprocessor such as provided by software 86. The programming from the software 86 is shown as being introduced to the microprocessor 80 to control the operation of the microprocessor in selecting the two hundred and fifty six (256) values from the 766 available values to provide the gamma correction curve 84 in Figure 14. It will be appreciated that different curves than the curve 84 can be provided by the software 86 and the microprocessor 80. For example, a curve 88 can be provided by the software 86 and the microprocessor 80.

Alternatively, the portions 34a, 34b and 34c in each pixel can also be used to cumulatively provide 766 different values. All of the 766 values may be used by the microprocessor 80 to provide gray scale values. The 766 values may be

provided by the microprocessor 80 under the control of the software 86. The operation of the microprocessor 80 to provide the 766 gray scale values for each pixel 34 causes an enhanced resolution in the gray scale to be produced by providing an increased number of gray scale levels which can be selected for each pixel.

Figure 16 provides a simplified block diagram, generally indicated at 100, of a system in the prior art for providing a display of an image in a display monitor. As shown, the system 100 includes a microprocessor such as a personal computer 102. The computer 102 introduces successive pluralities of binary bits indicative of color to a frame buffer 104 which receives and stores the successive pluralities of binary bits. For example, each plurality may include eight (8) binary bits and may indicate one of three (3) primary hues, namely red, green and blue. Each plurality of binary bits may alternatively indicate a gray scale value for a pixel to be displayed on a monitor in a panel display. The pluralities of binary bits are converted by a converter 106 to analog voltages indicative of the pluralities of binary bits. The analog voltages from the converter 106 are introduced to a display 108 such as a cathode ray tube to provide a color dependent upon the value represented by each individual one of the pluralities of binary bits. Alternatively, the analog voltages may provide a gray scale image on the display 108.

Figure 17 shows a preferred embodiment, generally indicated at 110, of the invention for use with the flat panel display 40. The system 110 includes a microprocessor such as a personal computer 112 corresponding to the personal computer 102 in Figure 16. The pluralities of binary indications from the personal computer 112 are introduced to a frame buffer 114 corresponding to the frame buffer 104 in Figure 16. The binary indications from the frame buffer 114 in turn pass to a look-up table 116 in Figure 17. Look-up tables such as the table 116 are

known in the art but not in the combination of stages shown in Figure 17. For example, when each plurality of binary signals has eight (8) binary bits, the look-up table 116 may have 256 positions. Each position in the look-up table 116 may provide an indication of an individual gray scale value. This value may be provided by a plurality of binary bits greater than 8. For example, each plurality of eight (8) binary bits from the frame buffer 114 may be converted to a sequence as high as twenty-four (24) binary bits in the look-up table 116.

The pluralities of the binary bits from the look-up table 116 are converted by a converter 118 to analog voltages indicative of the pluralities of the binary bits. The analog voltages from the converter 118 are introduced to the flat panel display 40 shown in Figure 7. In this way, the flat panel display 40 provides an indication for each pixel with more sensitive gray scale levels than the levels indicated by the pluralities of eight (8) binary bits from the frame buffer 114. Furthermore, different relationships between the different values of the pluralities of binary bits and the gray scale levels represented between white and black by such pluralities may be provided. For example, the look-up table (LUT) 116 may be used to provide a gamma correction curve representing the response of the human eye to different levels of brightness. A typical gamma correction curve is indicated at 119 in Figure 18. In Figure 18, progressive values of the analog voltage are indicated along the horizontal axis and progressive values of the image brightness are indicated along the vertical axis.

Figure 19 shows another preferred embodiment, generally indicated at 120, of the invention. The embodiment shown in Figure 19 includes a personal computer 122, a frame buffer 124 corresponding to the frame buffer 114, and a look-up table 126 for replacing the look-up table 116 in Figure 19. The look-up table 126 receives the plurality (e.g. 8) of binary bits from each of the portions 34a, 34b and

34c in the pixel 34 and converts the combined indications from the three (3) pixel portions to 766 gray scale levels.

The personal computer 122 processes the binary bits from the portions 34a, 34b and 34c for each pixel 34 so that the number of available values is increased from 256 to 766. The number of available values is 3 (256)-2=766 because each of the portions 34b and 34c does not provide a value for the last digital position. From the standpoint of a $\log_2$ analysis to determine the equivalent number of binary bits, this provides an increase in the effective number of binary bits for each pixel 34 from $2^{8\text{ to}}$ approximately $2^{9.58}$ binary bits.

Since $2^8 = 256$, the pixel portion 34a indicates $2^8 = 256$ binary bits when eight (8) binary bits are provided for the pixel portion. The pixel portion 34b provides 256 additional positions each indicating an individual value for the ninth (9th) binary bit. As will be appreciated, the 9th binary bit is represented by 256 binary positions. Thus, the pixel portions 34a and 34b cumulatively indicate 2^9 binary bits. The tenth (10th) binary bit is indicated by an additional 512 positions. However, the pixel portion 34c can provide only 254 positions. This is approximately 0.58 of the tenth (10th) binary bit. Thus, the pixel portions 34a, 34b and 34c cumulatively indicate $2^{9.58}$ binary bits.

A gray scale image with a digital representation of $2.^{9.58}$ binary bits provides a significantly enhanced contrast between different shades of gray than a gray scale image with a digital representation of only 2^8 binary bits. Furthermore, this enhanced contrast between light pixels and dark pixels is provided in the preferred embodiment of the invention shown in Figure 19 without changing the number of the pixels in the display monitor.

The digital representations of $2^{9.58}$ binary bits from the pixel portions 34a, 34b and 34c for each pixel 34 are converted by a digital-to-analog converter 128 to corresponding analog voltages. The analog voltage for each pixel 34 is introduced to the pixel in the flat panel display 40 to provide a gray image with a scale of enhanced sensitivity.

Figure 20 shows another preferred embodiment, generally indicated at 130, of the invention. The preferred embodiment 130 includes a personal computer 132, a frame buffer 134, a look-up table 13 and the flat panel display 40. The frame buffer provides twelve (12) binary bits out of the twenty-four (24) binary bits cumulatively provided by the pixel portions 34a, 34b and 34c of the pixel 34. The look-up table 136 receives the 12 binary bits from the frame buffer 134 for each pixel and converts these binary bits to digital representations for the pixel such as indicated by 24 binary bits. This enhances the contrasts between the different gray scale representations. The digital representations from the look-up table 136 for each pixel are introduced to a digital-to-analog converter 138 which produces an analog voltage indicative of the digital representations. The analog voltage causes a gray scale image to be produced on the flat panel display 40 for the pixel.

Figure 21 provides a preferred embodiment, generally indicated at 140, which can be considered as similar to, and actually an extension of, the preferred embodiment shown in Figure 20. In the embodiment shown in Figure 21, a first particular number of binary bits (e.g. 12) of the 24 binary bits cumulatively available from the pixel portions 34a, 34b and 34c of the pixel 34 are introduced by a personal computer 142 to a frame buffer 144. The binary indications from the frame buffer 144 pass through a first bus 146 to a first look-up table 148. The frame buffer 144 may correspond to the frame buffer 134 in Figure 20 and the look-up table 148 may correspond to the look-up table 136 in Figure 20.

The look-up table 148 may provide a conversion corresponding to the conversion discussed above in connection with the embodiment shown in Figure 20. In other words, the look-up table 148 may convert the 12 binary bits for each pixel to a particular number such as 24 binary bits. The converted indications from the look-up table 148 are converted to analog voltages by a converter 150 and the analog voltages are is introduced to a flat panel display 40a corresponding to the flat panel display 40 in Figure 20 to provide an image with an enhanced gray scale resolution.

In like manner, the other 12 binary bits cumulatively provided by the frame buffer 144 for the portions 34a, 34b and 34c in each pixel 34 are introduced through a bus 152 to a look-up table 154 which may correspond to the look-up table 148. The look-up table 154 may convert the other 12 binary bits for each pixel to a particular number (e.g. 24) of binary bits. The 24 binary bits for each pixel are converted by a converter 154 to an analog voltage and the analog voltage is introduced to a flat panel display 40b corresponding to the panel 40a. The flat panel display 40b may provide an image with an enhanced gray scale resolution. In this way, the 24 binary bits cumulatively provided by the portions 34a, 34b and 34c of each pixel are converted to two (2) different digital representations for display respectively on the flat panel displays 40a and 40b.

Figure 22 provides an additional preferred embodiment, generally indicated at 160, of the invention. In the preferred embodiment 160, a look-up table 162 may convert a particular number (e.g. 8) of binary bits in a pixel to a different number (e.g. 24) of binary bits. The binary bits (e.g. 24) from the look-up table 162 for the pixel may represent a pseudo color. These binary bits may be converted to an analog voltage by a converter 164 and the analog voltage may be introduced to a

flat panel display 166 in Figure 22 to provide an image in a pseudo color. The flat color display may include the color filters 32 in Figure 2.

Figure 23 is a schematic diagram of successive sweeps of lines 200 of the pixels in the flat panel display 40 when the flat panel display is disposed in a landscape mode. As will be seen, successive sweep of the pixels are in a substantially horizontal direction. In a landscape mode, the long dimension of the flat panel display is disposed in a horizontal direction and the short dimension of the flat panel display is disposed in a vertical direction. Successive lines of sweep are indicated in solid lines at 200 in Figure 23 and retraces from the end of each sweep to the beginning of the next sweet are indicated in broken lines at 202 in Figure 23. The use of displays in a landscape mode is known in the prior art.

Figure 24 is a schematic diagram of successive sweeps of lines 204 of the pixels in the flat panel display 40 when the flat panel display is disposed in a portrait mode. In a portrait mode, the short dimension of the flat panel display is disposed in the horizontal direction and the long dimension of the flat panel display is disposed in the vertical direction. In Figure 24, successive sweeps of the pixels are indicated in solid lines at 204 and the retrace from the end of each sweep to the beginning of the next sweep is indicated in broken lines at 206. The use of displays in a portrait mode is known in the prior art.

Assume that the flat panel display is initially in the landscape mode as indicated in Figure 23 and that there are 2048 pixels in each horizontal line and that there are 1536 pixels in the vertical direction as shown in Figure 25. As shown in Figure 25, the first line of sweep in the landscape mode of Figure 25 extends from 0 to 2047 pixels. The second line of sweep extends from 2048 to 4095 pixels and the third line of sweep extends from 4096 to 6143 pixels.

Assume that the display is rotated through an angle of 90° to be in the portrait mode shown in Figure 24. Because of the rotation of 90°, the sweep in successive lines is downwardly as shown at 204 in Figure 24. Assume that each of the vertical lines 204 has 2048 pixels and that there are 1536 pixels in the horizontal direction in Figure 26. The first pixel in the first vertical line would accordingly be 0; the first pixel in the second vertical line would be 2048; and the first pixel in the third vertical line would be 4096, all as shown in Figure 26.

In order to provide a sweep of lines in the horizontal direction, the sequence of pixels would have to be re-arranged in the horizontal direction in the portrait mode of Figure 26 so that pixels 0, 2048 and 4096 in the direction of the vertical sweep of Figure 26 would become pixels 0, 1 and 2 in the horizontal direction in Figure 27. The converted sweep in the horizontal direction is generally indicated at 208 in Figure 27.

Figure 28 is a schematic circuit diagram in block form of a system, generally indicated at 210, of the prior art for converting an image on the face of a display from a landscape mode to a portrait mode. The system includes a microprocessor such as a personal computer 212 for providing digital (e.g. binary code) indications of the gray scale level of the successive pixels in each successive line of scan.

The lines in the landscape mode of Figure 25 in the personal computer 212 are converted by software 214 to lines in the portrait mode of Figure 27. However, the conversion of the lines of sweep from the landscape mode of Figure 25 to the portrait mode of Figure 27 is relatively slow because of the respective transition of pixels such as pixels 0, 2048 and 4096 in the landscape mode to pixels 0, 1 and 2 in the portrait mode of Figure 27.

The binary indications representing the transitioned pixels from the software 214 are introduced to a frame buffer 216 which constitutes a memory for storing the pixels. The binary indications representing the transitioned pixels are converted by a digital-to-converter 218 to analog voltages and the analog voltages are introduced to a display 220 for the production on the face of the display of an image representative of the binary indications. The display 220 may constitute the flat panel display 40 shown in Figure 7.

Figure 29 is a circuit diagram in block form of a system, generally indicated at 222, constituting a preferred embodiment of the invention. The system 222 includes a microprocessor such as a personal computer 224. The personal computer 224 scans the successive lines in a horizontal direction as shown in Figure 25. The scan is in the form of binary indications for the successive pixels in each horizontal line of scan.

The binary indications from the personal computer 224 are introduced to a frame buffer 226 which stores the binary indications in the form that they are received so that the binary indications provide successive lines of scan in the horizontal direction. The binary indications stored in the frame buffer 226 are introduced to hardware such as an interface board 228. The board 228 constitutes hardware rather than software. The interface board 228 provides a rotary transition so that the 0, 2048 and 4096 pixels in the vertical sweep respectively become the 0, 1 and 2 pixels in the horizontal sweep. The binary indications from the interface board 12 are converted to analog voltages by a digital-to-analog converter 230. The analog voltages pass to a display 232, which may be the flat panel display 40 in Figure 7, for providing a gray scale image on the face of the display.

The rotary transitions in the pixel positions provided by the system 222 in Figure 29 occur in a significantly shorter period of time than the rotary transitions provided by the software 214 in the prior art system shown in Figure 28. This is particularly true when the display constitutes the flat panel display 40 since the flat panel display may have more pixels in each line of sweep than a typical cathode ray tube of the prior art.

The system 222 in Figure 29 includes the display 232 which may be the flat panel display 40. However, the system shown in Figure 29 can include a typical display, each as a cathode ray tube, of the prior art. The system 222 is especially advantageous, however, when it is used with the flat panel display 40 since the flat panel display can have an increased number of pixels in each line of sweep, thereby aggravating the problem of converting images in the landscape mode into images in the portrait mode. The system is particularly adapted to be used with x-rays providing gray scale images.

Although this invention has been disclosed and illustrated with reference to particular preferred embodiments, the principles involved are susceptible for use in numerous other embodiments which will be apparent to persons of ordinary skill in the art. The invention is, therefore to be limited only as indicated by the scope of the appended claims.

WHAT IS CLAIMED IS:

1. A method of forming a flat panel display for providing a gray scale image on a monitor in the display, including the steps of,

providing a flat panel display having a plurality of pixels for providing a color image, each pixel including a plurality of individual portions and including a plurality of color filters each providing an individual one of a plurality of colors to an individual one of the portions in the pixel,

removing the color filters from the color panel display, and

applying, to each of the portions in each of the pixels, a voltage indicating the gray scale of an image at that portion to obtain a display with an enhanced resolution of the gray scale image on the face of the monitor.

2. A method as set forth in claim 1 wherein

the voltage indicating the gray scale of the image at each portion in each pixel is in a digital form having a particular number of binary bits.

3. A method as set forth in claim 1 wherein

the monitor in the flat panel display has a plurality of rows of color pixels and a plurality of columns of color pixels and wherein each color pixel is substantially square and wherein each color pixel has a plurality of portions in the direction of the rows and wherein the voltage indicating the gray scale of the image is applied to each of the portions in each pixel in the successive rows to obtain the showing with the enhanced resolution of the gray scale image on the face of the monitor.

4. A method as set forth in claim 3 wherein

each pixel has a single portions in the direction of the columns and wherein a plurality of voltages are provided for different portions of each pixel in the direction of the columns corresponding to the different portions in the direction of the rows and wherein the plurality of the voltages provided for the different portions of each pixel in the direction of the columns are processed in a particular relationship to provide a particular gray scale image for each pixel.

5. A method of forming a flat panel display for providing a gray scale image on a monitor in the display, including the steps of:

providing a flat panel display having a plurality of pixels for providing a color image in each of the pixels, each pixel having a plurality of portions for providing different hues of the color in the image for the pixel,

operating upon the flat panel display to provide for the production of images in the gray scale in the different portions of each pixel in the flat panel display, and

introducing voltages in the gray scale to the different portions of each pixel in the flat panel display to produce on the monitor in the flat panel display a gray scale image represented by the voltages introduced to the different portions of the pixel.

6. A method as set forth in claim 5 wherein

each voltage for an individual one of the portions in each pixel is represented by a plurality of binary bits.

7. A method as set forth in claim 5 wherein

the different portions of each color pixel in the flat panel are disposed in rows and wherein each color pixel in the flat panel display is substantially square and wherein each of the different portions in each color pixel in the flat panel display is longer in the direction of the columns than in the direction of the rows.

8. A method as set forth in column 7 wherein

different voltages are provided for different portions of each pixel in the direction of the columns and wherein the different voltages for the different portions in each pixel in the direction of the columns are processed to provide a single voltage for producing a gray scale image for the different portions.

9. Apparatus for forming a flat panel display for providing a gray scale image

on a monitor in the display, including:

a flat panel display constructed before any change to provide a plurality of color pixels and to provide a color image in each color pixel, each color pixel including a plurality of color filters each providing an individual elemental color in an individual one of a plurality of portions in the pixel,

the color filters being removable from the flat panel display to provide for the display by the flat panel display of a gray scale image with an individual gray scale in each of the portions in each pixel, and

a voltage source for introducing a voltage with an individual gray scale to each of the portions in each of the pixels to provide the gray scale image on the monitor for each of the portions constituting a pixel in the gray scale image.

10. Apparatus as set forth in claim 9 wherein

there are a plurality of color filters for each color pixel in the flat panel display and wherein there are in each color pixel in the flat panel display a corresponding plurality of portions in each pixel, each portion being adapted to receive an elemental color and wherein the voltage source provides for an introduction of an individual gray scale image to each of the portions in each color pixel in the flat panel display to produce an image with an enhanced gray scale

resolution on the face of the display monitor and with each of the portions constituting a pixel in the gray scale image.

11. Apparatus as set forth in claim 9 wherein

the voltage from the source for each pixel in the gray scale image is in the form of a plurality of binary bits.

12. Apparatus as set forth in claim 9 wherein

each of the color pixels is substantially in the shape of a square and wherein the image on the face of the monitor in the flat panel display is formed from rows and columns of pixels and wherein the portions forming the pixels in the gray square images define the rows and wherein a plurality of voltages are provided for each pixel in the gray scale image in the direction of the columns and wherein the plurality of voltages for each pixel in the gray scale image in the direction of the columns are processed to provide a single voltage for selecting the gray scale for each pixel in the direction of the columns.

13. Apparatus for forming a flat panel display for providing a gray scale image

in a monitor in the flat panel display, including,

a flat panel display normally constructed to provide a color image represented by a particular number of color pixels and modified to present a gray scale image represented by a number of the gray scale pixels greater than the particular number, and

circuitry for introducing gray scale voltages to the increased number of gray scale pixels to provide for the display of the gray scale image on the face of the monitor.

14. Apparatus as set forth in claim 13 wherein

the circuitry introduces the gray scale voltages to the increased number of pixels in the form of a particular number of binary bits for each of the gray scale pixels to provide for the display of the gray scale image on the face of the monitor.

15. Apparatus as set forth in claim 13 wherein

the flat panel display is normally constructed to provide the color image in the form of a matrix of rows and columns of pixels each having a substantially quare configuration and wherein

the increased number of the gray scale pixels is in the direction of the rows but not in the direction of the columns.

16. Apparatus as set forth in claim 15 wherein

the increased number of the gray scale pixels in the direction of the rows causes the dimension of each of the gray scale pixels to be greater in the direction of the columns than in the direction of the rows and wherein

the circuitry provides an introduction of an individual one of the gray scale voltages to each of the gray scale pixels in the direction corresponding to the direction of the rows.

17. Apparatus as set forth in claim 16 wherein

the circuitry provides a plurality of the gray scale voltages for each of the gray scale pixels in the direction corresponding to the direction of the columns and wherein

the circuitry processes in a particular relationship the gray scale voltages for each pixel in the direction corresponding to the direction of the columns to enhance the resolution of the gray scale in the gray scale image.

18. A method of providing a gray scale image, including the steps of:

providing a flat panel display having a plurality of pixels for providing a color image in each of the pixels, each pixel having a plurality of portions for providing different hues of the color in an image for the pixel but not having any color filters for producing the different hues, and

providing for each portion of each pixel a plurality of binary bits to provide a gray scale image for each pixel with an enhanced sensitivity in the gray scale relative to the sensitivity which would be produced if there was only one portion in each pixel.

19. A method as set forth in claim 18, including the step of:

selecting for each pixel a particular plurality of the binary bits provided for the different portions of the pixel.

20. A method as set forth in claim 19 wherein

the particular plurality of the binary bits selected for each pixel is converted to an analog voltage which is applied to the pixel to produce the gray scale with the enhanced sensitivity for the pixel.

21. A method as set forth in claim 18 wherein

the pluralities of the binary bits for the different portions of each pixel are combined to provide for the pixel an effective number of binary bits greater than the particular number.

22. A method as set forth in claim 20 wherein

the combination of the pluralities of the binary bits from the different portions of each pixel provides for a production of the relationship between the

voltage representing the combinations of the pluralities of the binary bits for the pixel and the image brightness for the pixel and wherein

23. A method as set forth in claim 3 wherein

the combination of the pluralities of the binary bits from the different portions of each pixel is selected to provide for an enhancement in the image brightness of particular ones of the pixels relative to the image brightness for other ones of the pixels;

24. A method of providing a gray scale image, including the steps of:

providing a flat panel display having a plurality of pixels each responsive to a plurality of filters for providing a color image, each pixel including a plurality of individual portions and normally including an individual one of the color filters for each filter portion but not actually including any color filter in the flat panel display, and

applying a particular number of binary bits to each of the individual portions in each pixel to provide for the pixel a plurality of binary bits greater than the particular number.

25. A method as set forth in claim 24, including the steps of:

converting the cumulative number of binary bits for each pixel to a voltage having a magnitude indicative of the value represented by the cumulative number of the binary bits.

26. A method as set forth in claim 25 wherein

the binary bits are selected in the cumulative number for each pixel to produce for the pixel a color gray with a level dependent upon the binary bits selected in the particular number;

27. A method of providing a gray scale image, including the steps of:

providing a flat panel display having a plurality of pixels for producing a color image in each of the pixels, each pixel having a plurality of portions for providing different hues of the color image for the pixel but not having any color filters for producing the different hues,

providing a particular number of binary bits for each portion of each pixel,

providing a plurality of digital representations each formed from a plurality of binary bits representative of a voltage for an individual one of the pixels, the number of the binary bits cumulatively provided in the different portions of each pixel being greater than the particular number of the binary bits in each portion of the pixel,

converting the binary bits cumulatively provided for the different portions of each pixel into a voltage indicative of the value represented by the binary bits cumulatively provided for the pixel, and

providing gray scale values in each of the pixels in accordance with the converted voltage for the pixel.

28. A method as set forth in claim 27, including the step of:

selecting particular ones of the digital representations for each pixel to establish an individual relationship for the pixel between the voltages represented by the selected digital representations and gray scales produced by the voltages.

29. A method of providing a gray scale image, including the steps of:

providing a flat panel display having a plurality of pixels for providing a color image, each pixel including a plurality of individual portions and normally including color filters for individual portions but with the color filters not included,

providing for each portion of each pixel a digital representation indicated by a particular number of binary bits, and

combining the digital representations for the different portions in each of the pixels to provide for the pixel a digital representation with a number of binary bits greater than the particular number to obtain an enhanced scale of gray for each pixel in accordance with the combined digital representations for the different portions of the pixel.

30. A method as set forth in claim 29, including the steps of:

the number of the binary bits in the digital representations for each pixel being greater than the particular number of binary bits, and

selecting a number of the digital representations corresponding to the number indicated by the particular number of the binary bits.

31. A method as set forth in claim 30 wherein

the selected digital representations for each pixel provide a curve of digital representations for the pixels vs brightness for the pixels corresponding to the gamma correction provided by the human eye.

32. A method as set forth in claim 29 wherein

the selected digital representations for each pixel provide a curve of digital representations for the pixels vs. brightness for the pixels different from the relationship provided by the flat panel display of digital representations for the pixels vs. brightness for the pixels.

33. A method of providing a gray scale image, including the steps of:

providing a flat panel display having a plurality of pixels for providing a color image, each pixel including a plurality of individual portions and normally including color filters for the individual portions but with the color filters not included,

providing for each portion of each pixel a digital representation indicated by a particular number of binary bits, and

selecting for each pixel a particular one of the digital representations indicated by the particular number of binary bits.

34. A method as set forth in claim 33 wherein

the number of the digital representations for the flat panel display corresponds to the number of the pixels in the flat panel display and wherein

the digital representations for each of the pixels in the flat panel display have the particular number of the binary bits.

35. A method as set forth in claim 33 wherein

the selected digital representations for each pixel provide a curve of digital representations for the pixels vs. brightness for the pixels corresponding to the gamma correction provided by the human eye.

36. A method as set forth in claim 33 wherein

the selected digital representations for each pixel provide a curve of digital representations for the pixels vs. brightness for the pixels different from the relationship provided by the flat panel display of digital representations for the pixels vs. brightness for the pixels.

37. Apparatus for providing a gray scale image, including,

a flat panel display normally including a plurality of color filters for forming for each of a plurality of pixels a color defined by a plurality of different hues each introduced to an individual of a plurality of portions of the pixel from an individual one of the color filters but with the color filters removed to provide a gray image with an individual gray scale value for each of the pixels,

a source of a plurality of first digital representations each defined by a particular number of binary bits, the source being constructed to introduce each of the digital representations to an individual one of the particular portions of an individual one of the pixels, and

electrical circuitry for combining the digital representations for the different portions in each of the pixels to provide for the pixel second digital representations with numbers of binary bits greater than the particular number.

38. Apparatus as set forth in claim 37 wherein

the electrical circuitry converts each of the first digital representations to an analog voltage for introduction to an individual one of the terminals dependent upon the magnitude of the voltage.

39. Apparatus as set forth in claim 38 wherein

the electrical circuitry combines the digital representations in the different portions of each of the pixels to provide for one of the digital portions of each of the pixels the particular number of the binary bits for the pixel and to define for the other portions of the pixel values of the binary bits for the pixel in excess of the particular number of binary bits.

40. Apparatus as set forth in claim 39 wherein

the electrical circuitry converts the digital representations for each of the pixels to a voltage indicative of the digital representations and wherein the electrical circuitry provides a monochromatic color for each of the pixels with a gray scale value dependent upon the voltage produced for the pixel.

41. A method of providing a gray scale image, including the steps of:

providing a flat panel display having a plurality of pixels for providing a color image in each of the pixels, each pixel having a plurality of portions for providing different hues of the color in an image for the pixel but not having any color filters for producing the different hues,

providing a particular number of binary indications for each of the portions in each pixel,

introducing to a frame buffer the particular number of the binary indications for each of the portions in each pixel,

converting in a look-up table the binary indications from the frame buffer for each of the pixels to binary indications different for each of the pixels from the binary indications from the frame buffer, and

providing on the flat panel display a gray color representative of the different binary indications for each of the pixels from the look-up table.

42. A method as set forth in claim 41, including the steps of:

converting in the look-up table the cumulative binary indications for different portions in each pixel from the frame buffer to the different binary indications for each of the pixels from the look-up table.

43. A method as set forth in claim 42, including the steps of:

selecting the binary indications from the look-up table for a particular number of the pixels, and

providing on the flat panel display a gray color representative of the binary indications for each of the pixels selected from the look-up table.

44. A method as set forth in claim 41, including the steps of:

providing for a first one of the portions in each pixel binary indications representing a particular number of binary bits, for a second one of the portions in

each pixel binary indications representing a bit of higher binary significance than the particular number of binary bits, and for the third one of the portions in each pixel binary indications representing a bit of even higher binary significance than the bit of higher binary significance, and

introducing the binary indications for the first, second and third portions in each pixel to the look-up table to obtain the conversion of the binary indications in the look-up table to the different binary indications.

45. A method as set forth in claim 44, including the step of:

providing from the look-up table binary indications individual to the binary indications from the first portion of each pixel, individual to the combination of the binary indications from the first and second portions of the pixel and individual to the binary indications from the combination of the first, second and third portions of the pixel.

46. A method as set forth in claim 45 wherein

a particular number of the binary indications from the combination of the first, second and third portions in each pixel are introduced from the frame buffer to the look-up table to provide for the production by the look-up table of the different binary indications and to provide for the introduction to the flat panel display of the binary indications produced by the look-up table.

47. A method as set forth in claim 46 wherein

the look-up table constitutes a first look-up table and the flat panel display constitutes a first flat panel display and wherein

the particular number of the binary indications introduced from the frame buffer to the first look-up table for each of the pixels constitutes a first particular number and wherein

the particular number of the binary indications are introduced from the frame buffer to the first look-up table through a first bus and wherein

a second particular number of the binary indications, different from the first particular number, from the frame buffer are introduced through a second bus to a second look-up table for conversion by the second look-up table to binary indications different from the binary indications introduced to the second look-up table and wherein

the binary indications from the second look-up table are introduced to a second flat panel display for a production on the second flat panel display of an image represented by the binary indications introduced to the second flat panel display.

48. A method of providing a gray scale image, including the steps of:

providing a flat panel display having a plurality of pixels each having a plurality of portions for receiving light in particular colors from color filters, the flat panel display not including the color filters thereby providing for a display of a gray scale image by the pixels in the flat panel display,

providing a particular number of binary indications for each of the portions in each pixel,

introducing to a frame buffer the particular number of the binary indications for each of the pixel portions in each pixel,

converting in a look-up table the binary indications from the frame buffer for the pixel portions to binary indications different for the pixel portions from the binary indications from the frame buffer, and

providing on the flat panel display a gray color representative of the binary indications from the look-up table.

49. A method as set forth in claim 48 wherein

the look-up table converts particular ones of the binary indications for each of the pixels to binary indications stored in the look-up table.

50. A method as set forth in claim 48 wherein

the look-up table converts, to binary indications stored in the look-up table, the binary indications for each of the portions in each pixel and wherein

the flat panel display provides a gray color for each of the portions in each pixel in accordance with the converted binary indications from the look-up table for the portion in the pixel.

51. A method as set forth in claim 48 wherein

the look-up table converts, to binary indications stored in the look-up table, particular ones of the binary indications cumulatively stored in the frame buffer for the pixel and wherein

the flat panel display provides a gray color for each pixel in accordance with the converted binary indications from the look-up table for the pixel.

52. A method as set forth in claim 51 wherein

the look-up table constitutes a first look-up table and the particular ones of the binary indications cumulatively stored in the frame buffer for the pixel constitute first particular ones of the binary indications and wherein the flat panel display constitutes a first flat panel display and wherein

second particular ones of the binary indications for each of the pixels are introduced to the frame buffer and wherein

a second look-up table converts, to binary indications stored in the second look-up table, the second particular ones of the binary indications stored in the frame buffer and wherein

a second flat panel display provides a gray color for each pixel in accordance with the converted binary indications from the second look-up table for the pixel.

53. A method of providing a gray scale image, including the steps of:

providing a flat panel display having a plurality of pixels each having a plurality of portions for receiving light in particular colors from color filters, the flat panel display not including the color filters thereby providing for a display of a gray scale image by the pixel in the flat panel display,

providing a particular number of binary indications for each of the portions in each pixel,

converting in a look-up table the binary indications for portions in each pixel to a digital representation different from the binary indications,

converting the digital representations for the portions in each pixel to analog voltages indicative of the binary representations, and

applying the analog voltages for the portions in each pixel to the pixel in the flat panel display to provide images with a gray scale level dependent upon the analog voltages.

54. A method as set forth in claim 53 wherein

a particular number of the cumulative binary indications for the pixel portions in each pixel are introduced to the look-up table to obtain a conversion of these binary indications by the look-up table to digital representations and wherein

the digital representations from the look-up table of the cumulative binary indications for the pixel portions in each pixel are converted to analog voltages and wherein

the analog voltage for each of the digital representations from the look-up table is applied to an individual one of the pixels in the flat panel display to provide an image with a gray scale level dependent upon the analog voltage.

55. A method as set forth in claim 53 wherein

the look-up table converts the particular number of the binary indications for each of the portions in each pixel to digital representations of the pixel portion and wherein

the digital representations from the look-up table for each of the pixel portions are converted to an analog voltage and wherein

the analog voltage for each of the pixel portions is applied to an individual one of the pixel portions in the flat panel display to provide an image with a gray scale level dependent upon the analog voltage.

56. A method as set forth in claim 53 wherein

the binary indications from the pixel portions for each pixel cumulatively provide a number of binary indications greater than the particular number and wherein

the cumulative binary indications for each pixel are introduced to the look-up table to obtain digital representations for the pixel and wherein

the digital representations for each pixel are converted to an analog voltage indicative of the digital representations and wherein

the analog voltage for each pixel is applied to the pixel in the flat panel display to provide an image with a gray scale level dependent upon the analog voltage.

57. Apparatus for providing a gray scale image, including,

a flat panel display having a plurality of pixels and having a plurality of pixel portions for each pixel and normally having color filters for applying each of a plurality of different hues to an individual one of the portions for each pixel, the color filters not being included in the flat panel display,

a microprocessor for providing pluralities of binary indications, each of the pluralities of binary indications providing an indication of the gray scale to be provided on one of the pixel portions in the flat panel display,

a look-up table responsive to the pluralities of binary indications for providing digital representations of the binary indications, the digital representations being different from the binary indications, and

means for providing gray scale images on the portions of the pixels in the flat panel display in accordance with the digital representations from the look-up table.

58. Apparatus as set forth in claim 57, including:

a frame buffer for storing the pluralities of binary indications from the microprocessor and for introducing the pluralities of binary indications to the look-up table.

59. Apparatus as set forth in claim 57, including,

a digital-to-analog converter for converting the digital representations from the look-up table to analog voltages and for introducing the analog voltages to the portions in the pixels to produce the gray scale image in the flat panel display.

60. Apparatus as set forth in claim 57 wherein

the digital representations for the binary indications in each of the pluralities have a different number then the number of the binary indications in each of the pluralities.

61. Apparatus as set forth in claim 57 wherein

a particular number of binary indications is provided for each portion in each pixel and wherein

the number of the binary indications in each of the pluralities is greater than the particular number but less than the number of binary indications cumulatively in the portions of each pixel.

62. Apparatus as set forth in claim 57 wherein

a particular number of binary indications is provided for each portion in each pixel and wherein

the number of the binary indications in each plurality constitutes the particular number.

63. Apparatus as set forth in claim 57 wherein

a particular number of binary indications is provided for each portion in each pixel and wherein

the pluralities of binary indications constitute first pluralities and wherein

the look-up table constitutes a first look-table and wherein

the flat panel display constitutes a first flat panel display and wherein

a second flat panel display is provided with characteristics corresponding to those of the first flat panel display and wherein

the microprocessor provides second pluralities of binary indications and each of the second pluralities provides an indication of the gray scale to be provided on one of the pixel portions in the second flat panel display and wherein

a second look-up table is responsive to the second pluralities of binary indications for providing second digital representations of the binary indications in the second pluralities, the second digital representations being different from the binary indications in the second pluralities and wherein

means are included for providing gray scale images on the portions of the pixels in the second flat panel display in accordance with the digital representations from the second look-up table.

64. A method of providing a gray scale image, including the steps of:

providing a flat panel display having a plurality of pixels for providing a color image, each pixel including a plurality of individual portions and normally including color filters for the different portions but with the color filters not included, the flat panel display providing a sweep of successive lines of the pixels in a first direction,

providing a sweep of the successive lines of pixels in the first direction,

providing hardware to obtain a sweep of the pixel portions for each pixel in a second direction substantially perpendicular to the first direction,

introducing the pixels providing the sweep in the first direction to the hardware to obtain the sweep of the pixels in the second direction, and

introducing the pixel portions for each pixel from the interface board to the flat panel display to obtain a sweep of the pixels in the second direction.

65. A method as set forth in claim 64 wherein

a microprocessor provides binary indications representing the pixel portions in each pixel in the sweep of the successive lines of the pixels in the flat panel display.

66. A method as set forth in claim 64 wherein

the hardware constitutes an interface board.

67. A method as set forth in claim 64 wherein

the first direction is in a port rate mode and the second direction is in a landscape mode.

68. A method as set forth in claim 64 wherein

a memory stores the pixel portions for each pixel in the gray scale image in the sweep in the first direction before introducing the pixel portions for each pixel to the hardware to obtain a sweep of the pixel portions for the pixels.

69. A method of providing a gray scale image, including the steps of:

providing a display constructed to provide an image from a plurality of pixels arranged in successive rows and successive columns and to provide a sweep of the pixels in the successive rows and also to provide a sweep of the pixels in the successive columns,

providing hardware to convert a sweep of the pixels in the successive rows to a sweep of the pixels in the successive columns,

providing binary indications indicating the image to be provided for the pixels in the successive rows,

introducing the binary indications to the hardware to obtain the binary indications for the image to be provided for the pixels in the successive columns, and

introducing the images from the hardware to the display for each of the pixels in the successive columns to provide a visual representation of the image in the display.

70. A method of providing a gray scale image in one of a landscape made and a portrait mode, including the steps of:

providing a display having a plurality of pixels in a matrix relationship for displaying an image,

providing pluralities of binary indications in a sequence for producing an image in an individual one of the landscape and portrait modes, each plurality providing for a presentation of a gray scale image for one of the pixels in the display,

providing hardware for producing a re-arrangement of the pluralities of the binary indications in the sequence to produce the image in the other one of the landscape and portrait modes,

introducing the pluralities of binary indications in the sequence to the hardware to obtain the re-arrangement of the pluralities of binary images in the sequence for the production of the image in the other one of the landscape and portrait modes, and

providing a display of the image in the other one of the landscape and portrait modes in accordance with the re-arrangement in the sequence of the pluralities of the binary indications.

71. A method as set forth in claim 70 wherein

the pluralities of the binary indications in the re-arranged sequence are converted to analog voltages and wherein

the analog voltages are applied to the display to obtain the production of the image in the display in the other one of the landscape and portrait modes.

72. A method of providing a gray scale image in one of a landscape mode and a

portrait mode, including the steps of:

providing a flat panel display having a plurality of pixels and having in each pixel a plurality of portions each adapted to received light from an individual one of a plurality of color filters but without the inclusion of the color filters in the flat panel display thereby providing for the production of a gray scale image in the display,

providing pluralities of binary indications each providing for a display of a gray scale image on an individual one of the portions of an individual one of the pixels in the flat panel display, the pluralities of binary indications providing for a

display of the image in the flat panel display in an individual one of the landscape and portrait modes,

providing hardware for producing pluralities of binary indications representing a conversion of the image provided by the binary indications from the individual one of the portrait and landscape modes to the other one of the portrait and landscape modes,

introducing to the hardware the binary indications providing for a display of the image in the flat panel display in the individual one of the landscape and portrait modes to obtain the production of pluralities of binary indications providing for a display of the image in the flat panel display in the other one of the landscape and portrait modes, and

introducing the pluralities of the binary indications from the hardware to the flat panel display, and

providing for the display of the image in the flat panel display in the other one of the portrait and landscape modes.

73. In combination for providing a gray scale image in a particular one of landscape and portrait modes,

a flat panel display constructed to provide a plurality of pixels each having a plurality of portions for providing different hues in accordance with voltages applied to color filters, the flat panel display not including the color filters thereby providing a gray scale image,

a microprocessor for providing binary indications representing the gray scale image to be provided on each of the pixels in the flat panel display,

a frame buffer for storing the binary indications provided by the microprocessor,

an interface board operatively coupled to the frame buffer and responsive to the binary indications from the frame buffer for converting the binary indications

representing an image in one of the portrait and landscape modes to binary indications representing an image in the other one of the portrait and landscape modes,

a digital-to-analog converter for converting the digital indications from the interface board to analog voltages, and

means for introducing the analog voltages to the flat panel display to obtain a gray scale image on the flat panel display in the other one of the portrait and landscape modes.

74. In combination for providing a gray scale image in a particular one of landscape and portrait modes,

a flat panel display having a plurality of pixels and having a plurality of portions for each pixel and normally having color filters for introducing light of different hues to the individual ones of the pixel portions in each pixel but without the inclusion of the color filters in the flat panel display thereby providing for a gray scale image in the flat panel display,

a microprocessor for providing binary indications in a sequence for the pixel portions in each of the pixels in the flat panel display to provide for a gray scale image in the flat panel display in one of the landscape and portrait modes, and

an interface member for providing a re-arrangement of the binary indications from the microprocessor to provide for the production of the binary indications in a sequence providing a gray scale image in the flat panel display in the other one of the landscape and portrait modes.

75. In a combination as set forth in claim 74,

a digital-to-analog converter responsive to the binary indications from the interface member for converting the binary indications from the interface member

into analog voltages for introduction to the flat panel display to obtain a gray scale image on the flat panel display in the other one of the landscape and portrait modes.

FIG. 1
PRIOR ART

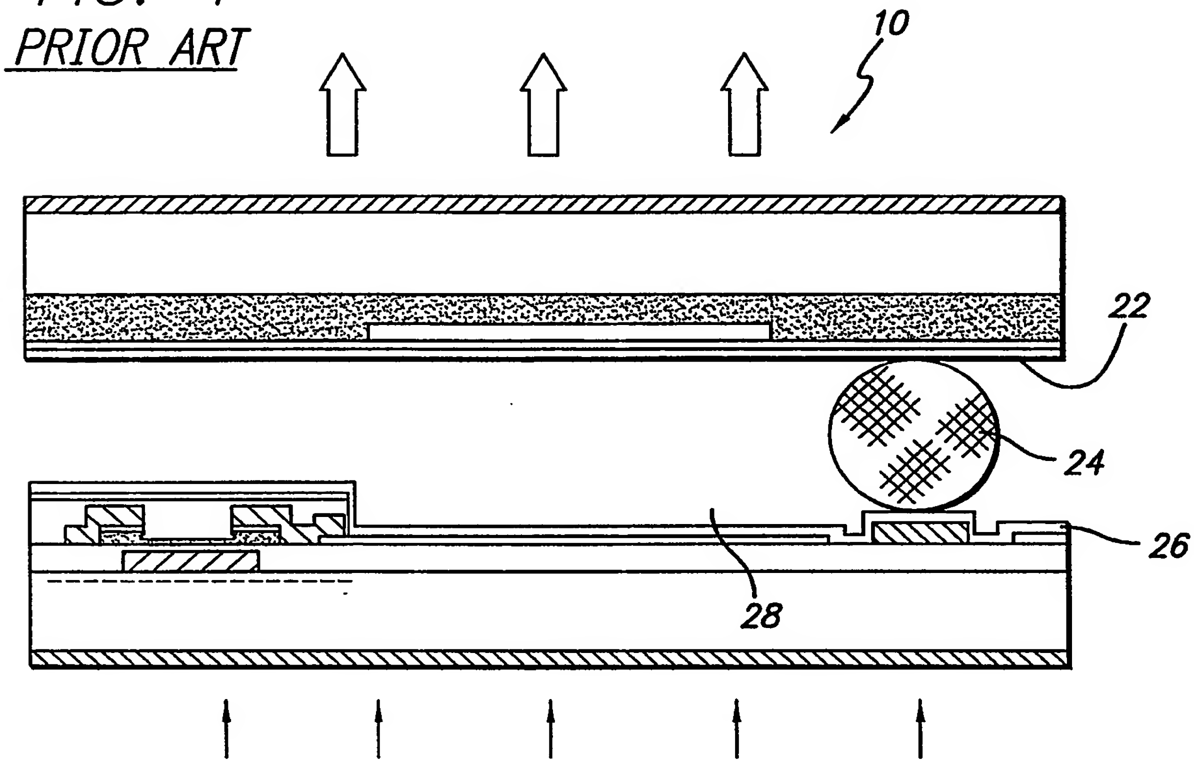


FIG. 2
PRIOR ART

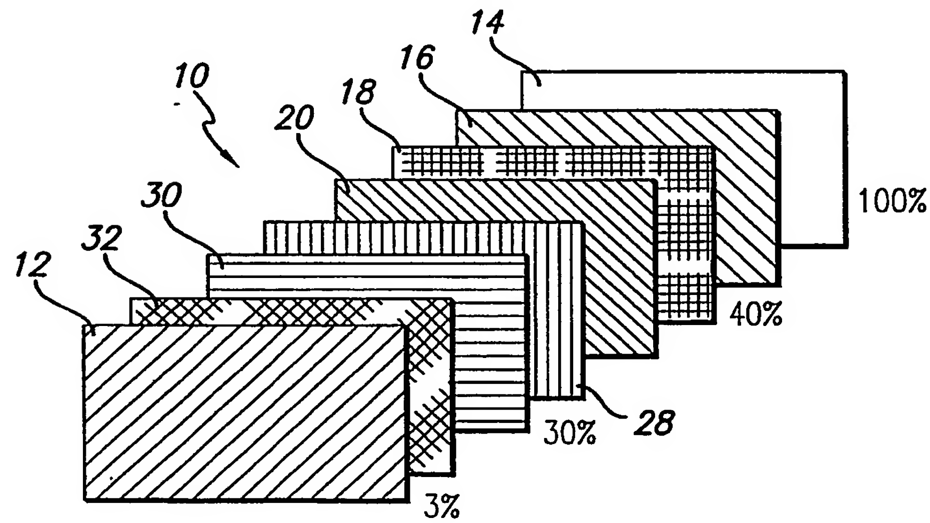


FIG. 3
PRIOR ART

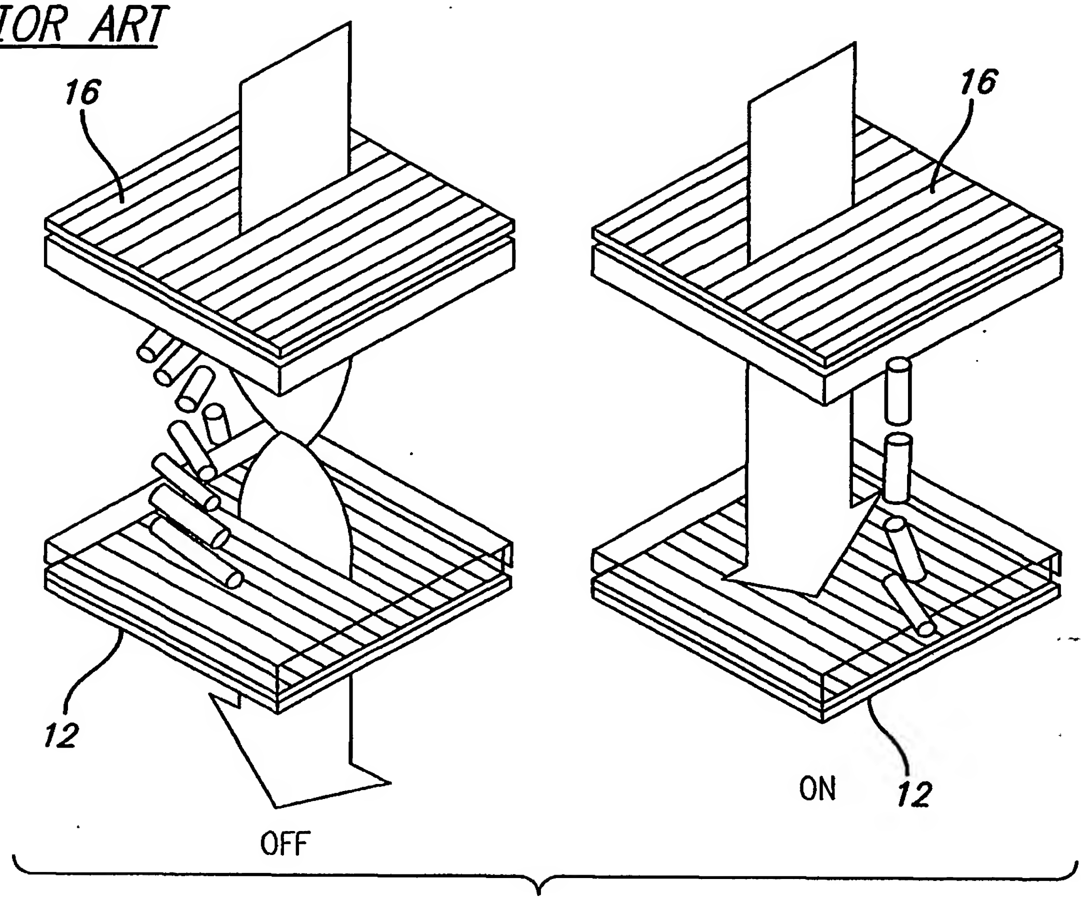
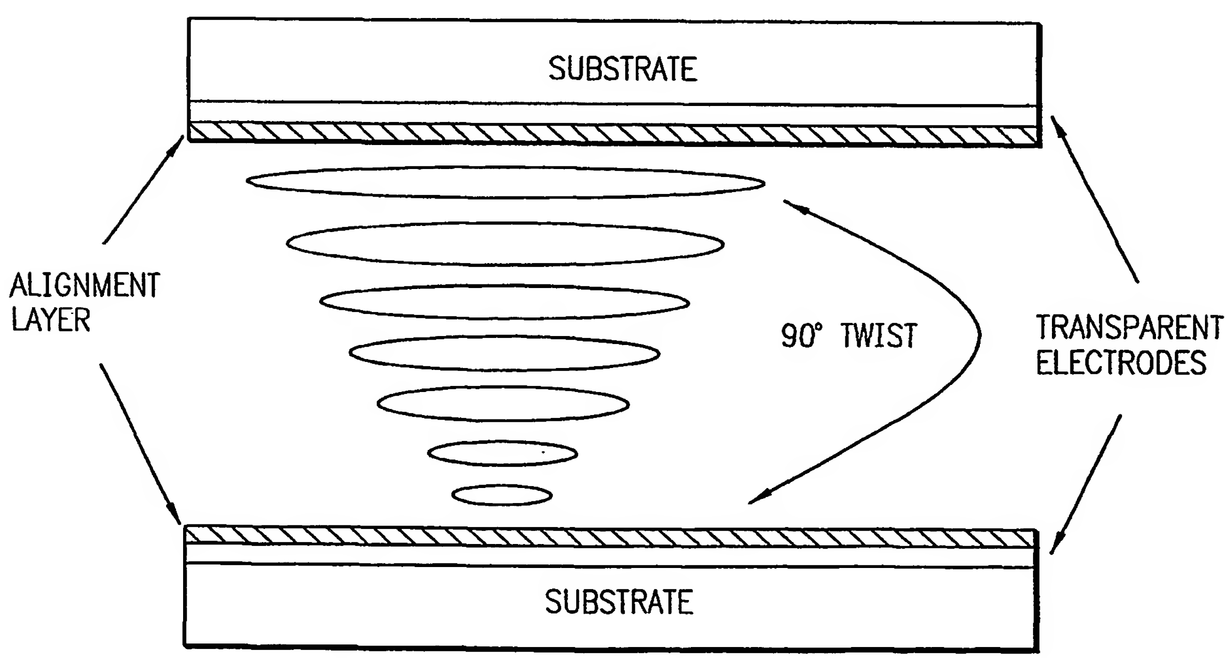


FIG. 4
PRIOR ART



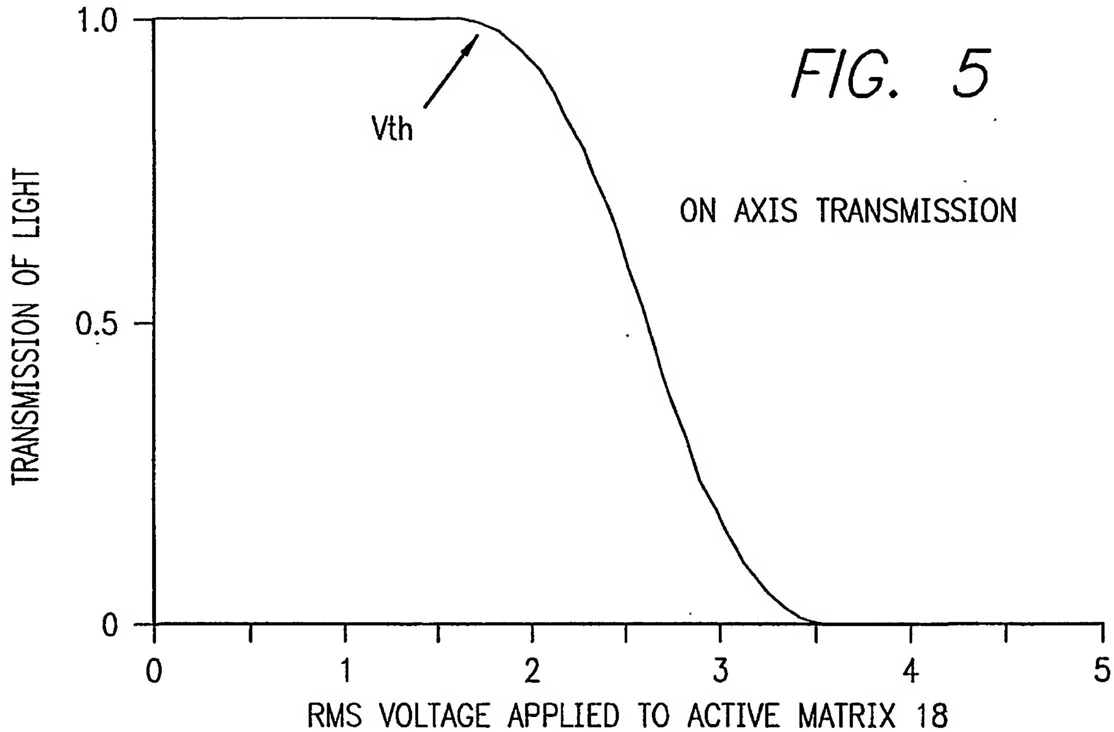


FIG. 5

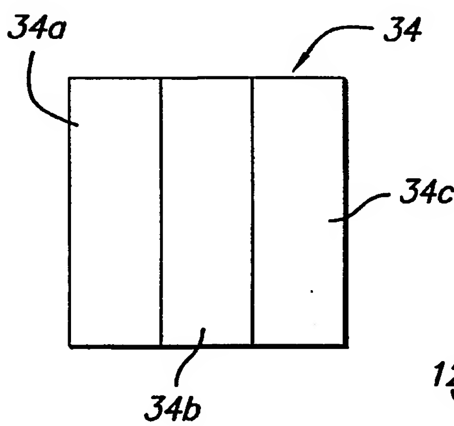


FIG. 6

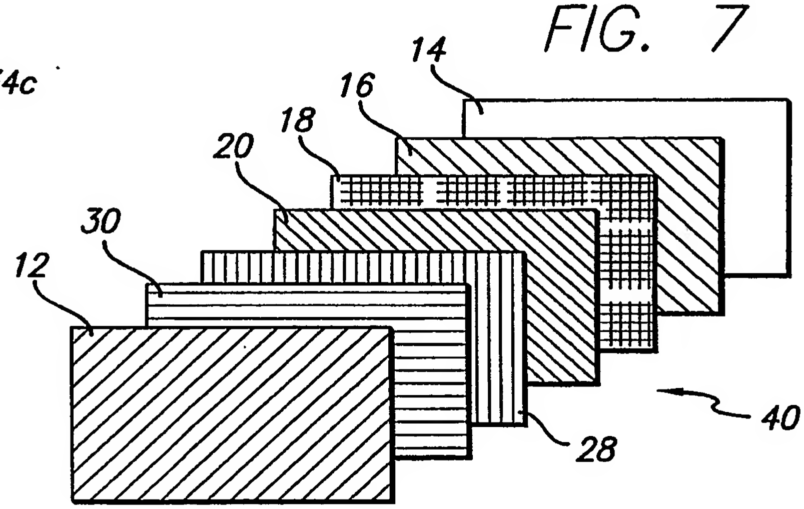
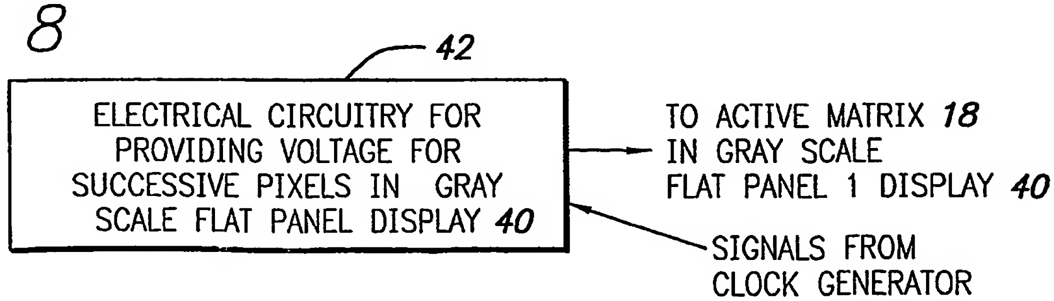


FIG. 7

FIG. 8



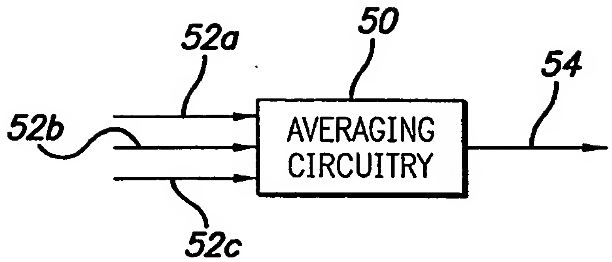


FIG. 9

FIG. 10

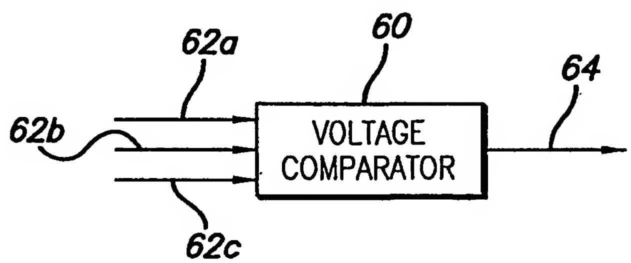


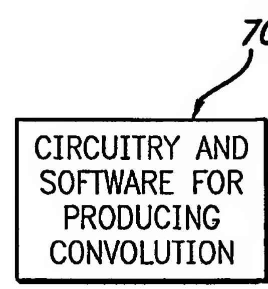
FIG. 11a

−1	−1	−1
−1	9	−1
−1	−1	−1

FIG. 11b

5	5	5
5	6	5
5	5	5

FIG. 12



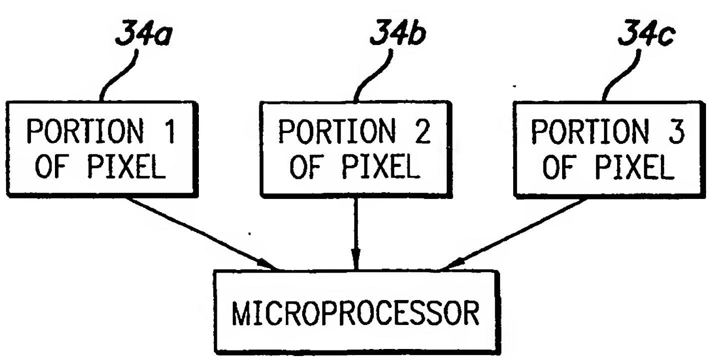


FIG. 13

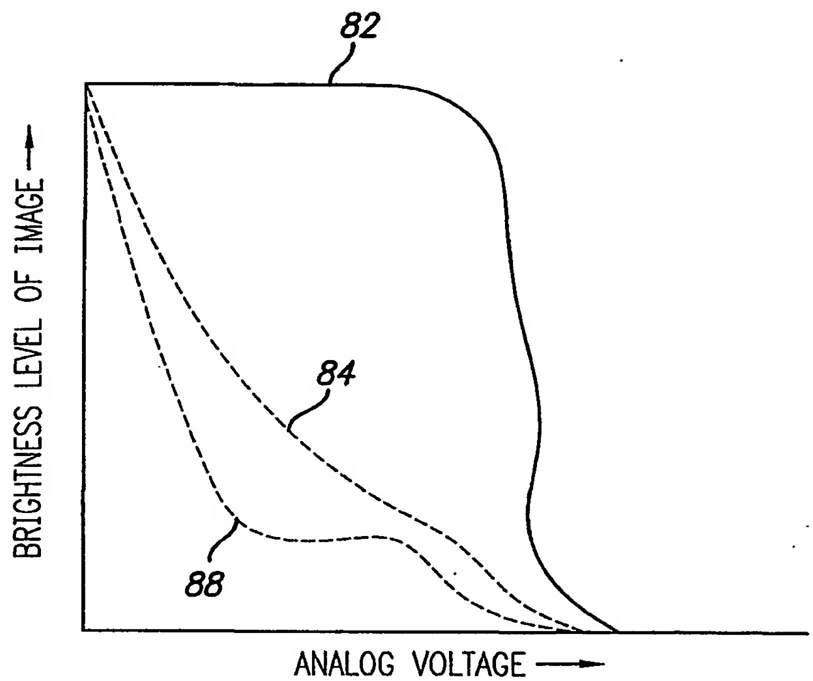


FIG. 14

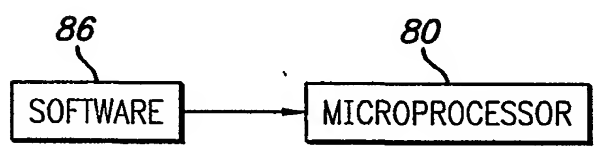


FIG. 15

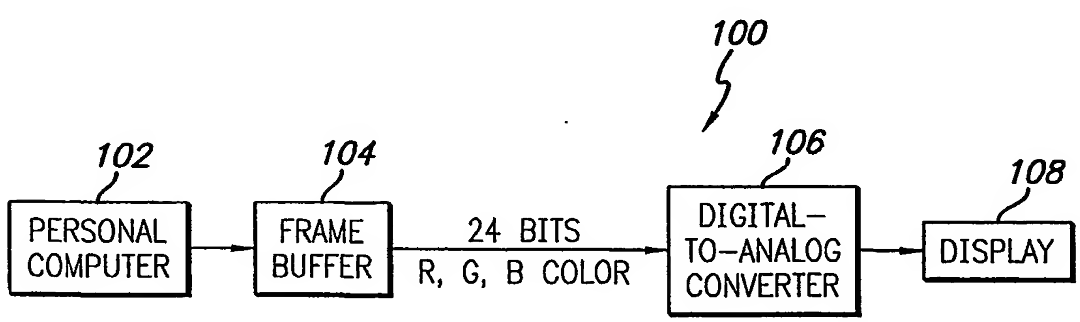


FIG. 16
PRIOR ART

FIG. 17

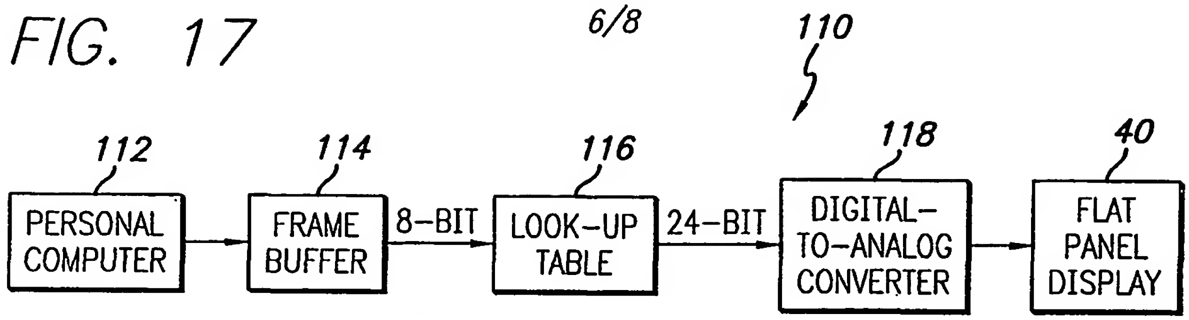


FIG. 18

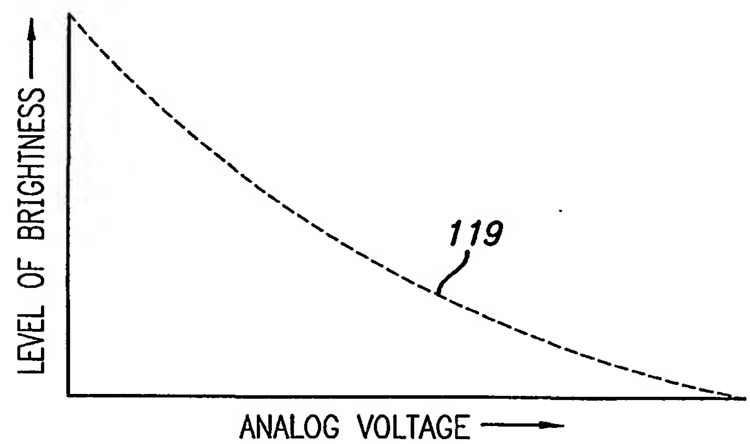


FIG. 19

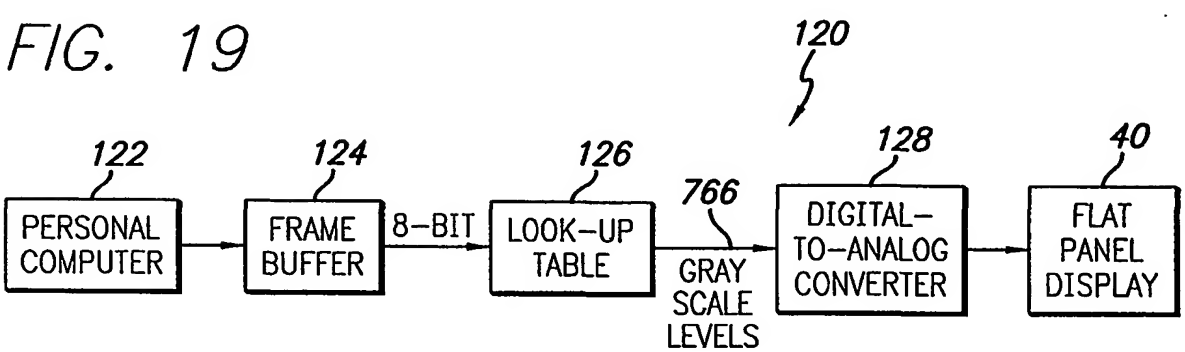


FIG. 20

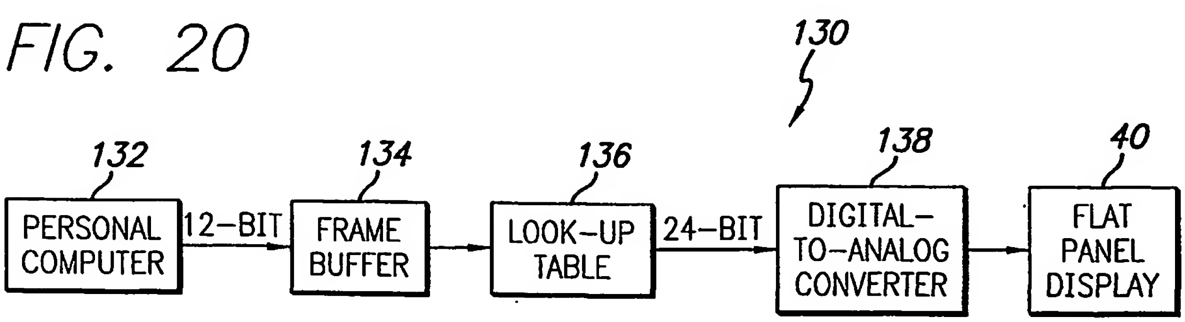


FIG. 21

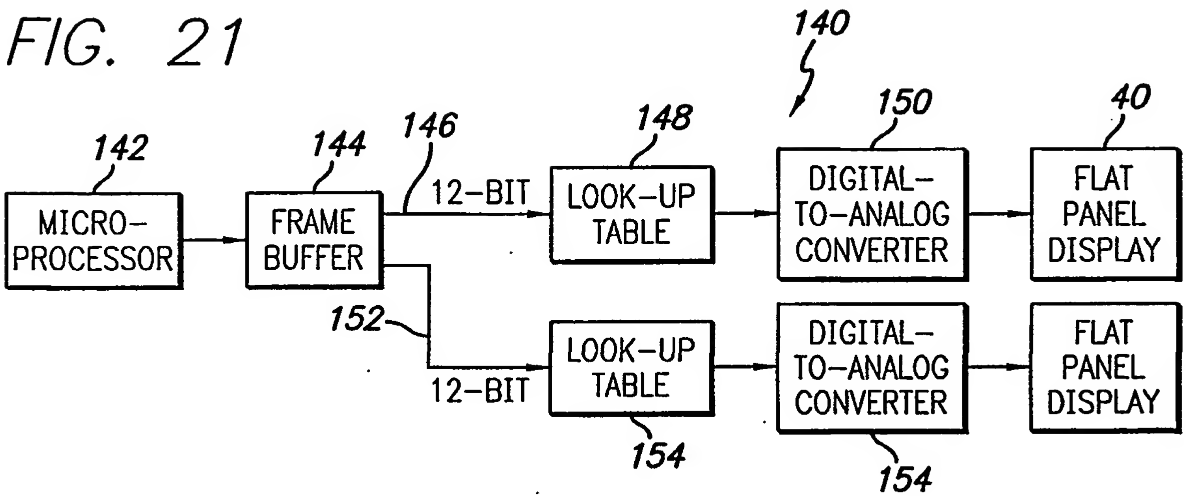
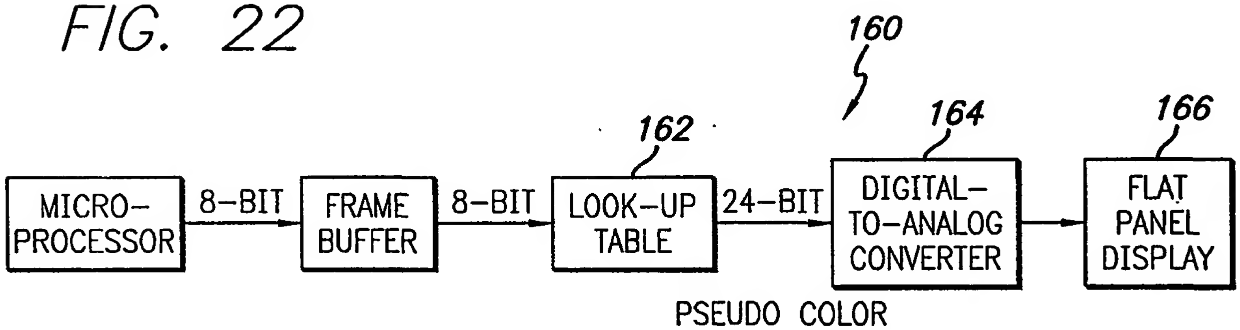


FIG. 22



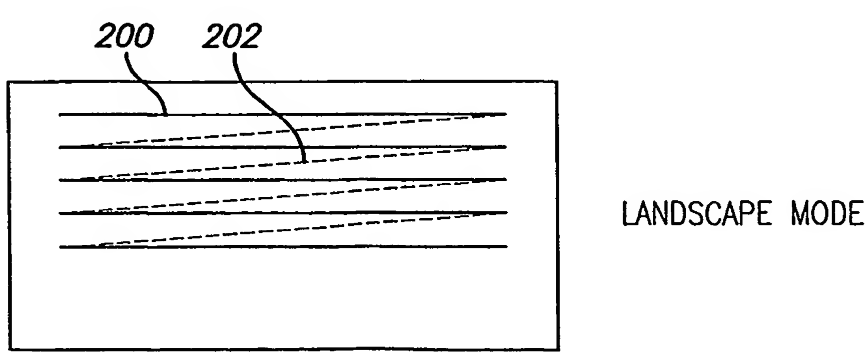
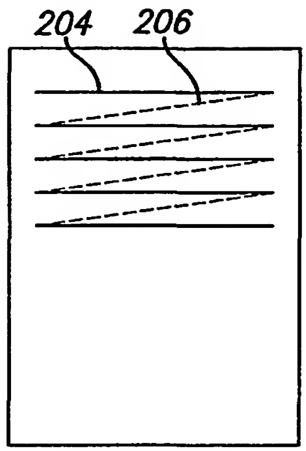
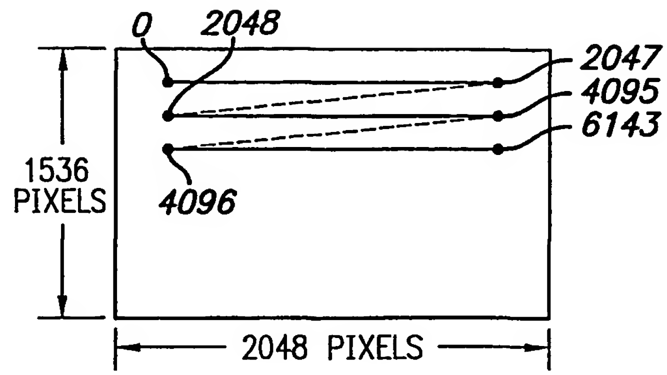


FIG. 23



PORTRAIT MODE

FIG. 24



LANDSCAPE MODE

FIG. 25

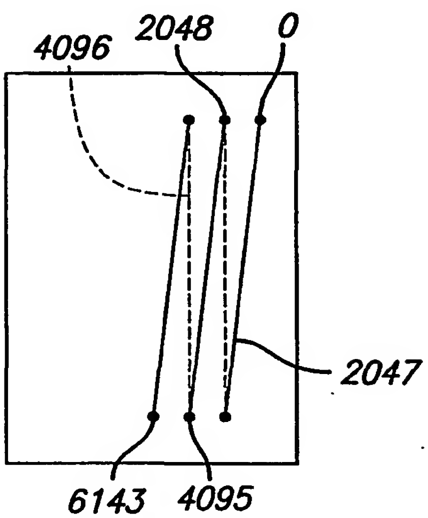


FIG. 26

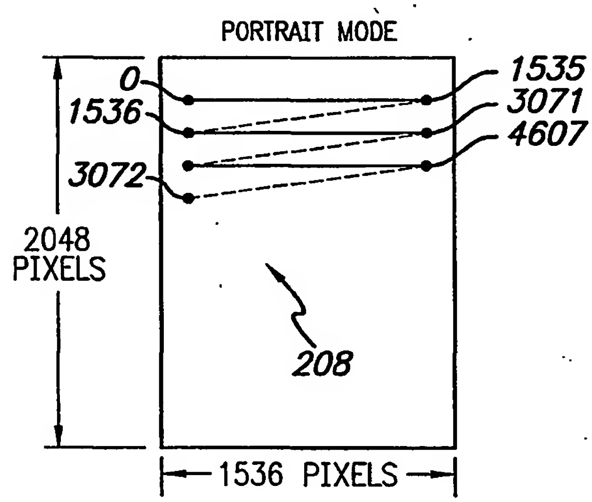


FIG. 27

FIG. 28

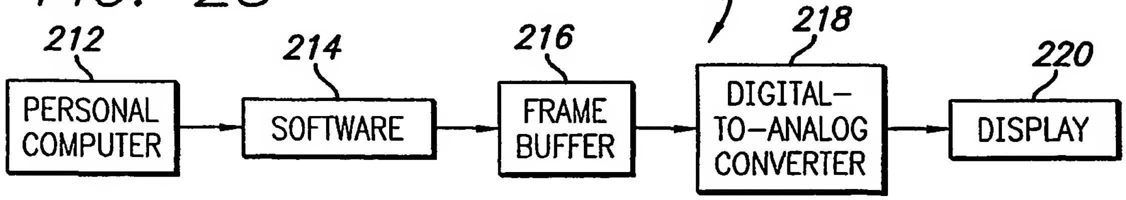
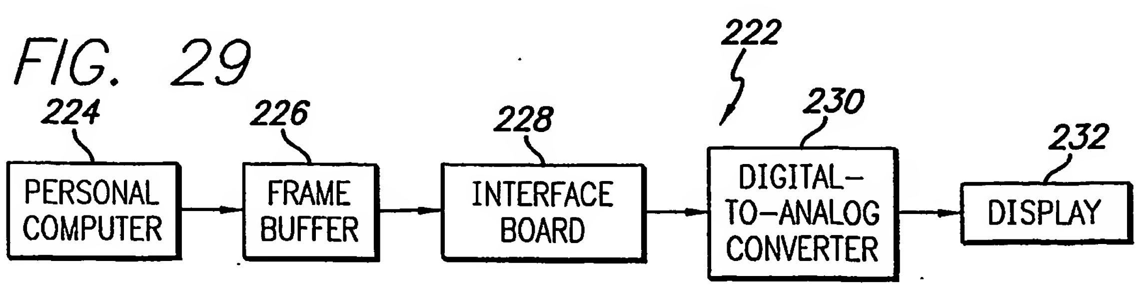


FIG. 29



INTERNATIONAL SEARCH REPORT

International application No.
PCT/US01/12150

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) : G09G 3/36, 5/00, 5/02, 5/04, 5/10
US CL : 345/3, 87-89, 147, 149, 150, 152-155

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
U.S. : 345/3, 87-89, 147, 149, 150, 152-155, 204

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4,739,312 A (OUDSHOORN et al) 19 April 1988, see all.	1-75
A	US 5,400,053 A (JOHARY et al) 21 March 1995, see all.	1-75
A	US 5,576,723 A (ASPREY) 19 November 1996, see all.	1-75

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search 16 June 2001 (16.06.2001)	Date of mailing of the international search report 08 AUG 2001
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703)305-3230	Authorized officer Kent Chang Telephone No. 703-305-9700